Appendix C
HUMAN HEALTH AND ACCIDENTS

Appendix C
HUMAN HEALTH, SAFETY, AND ACCIDENTS

This appendix to the Complex Transformation Supplemental Programmatic Environmental Impact Statement *(SPEIS) provides supplemental information pertaining to potential human health impacts associated with radiation exposures, chemical exposures, accidents, and worker safety issues due to operations of the major facilities (as identified in Chapter 3) associated with the programmatic alternatives analyzed. Located at the end of this appendix is a separate reference section.*

C.1 RADIOLOGICAL IMPACTS ON HUMAN HEALTH

C.1.1 Radiation and Radioactivity

Humans are constantly exposed to naturally occurring radiation through sources such as from the universe and from the Earth's rocks and soils. This type of radiation is referred to as *background radiation* and it is always around us. Background radiation remains relatively constant over time and is present in the environment today just as it was hundreds of years ago. In addition, humans are also exposed to manmade sources of radiation, including medical and dental x-rays, household smoke detectors, materials released from coal burning power plants, and nuclear facilities. The following sections describe some important principles concerning the nature, types, sources, and effects of radiation and radioactivity.

C.1.1.1 *What Is Radiation?*

Some atoms have large amounts of energy and are inherently unstable. They may reach a stable, less energetic state through the emission of subatomic particles or electromagnetic radiation, a process referred to as radioactivity. The main subatomic particles that comprise an atom are electrons, protons, and neutrons. *Electrons* are negatively charged particles that are principally responsible for chemical reactivity. *Protons* are positively charged particles, and *neutrons* are neutral. Protons and neutrons are located in the center of the atom, called the nucleus. Electrons reside in a designated space around the *nucleus*. The total number of protons in an atom is called its *atomic number*.

Atoms of different types are known as elements. There are more than 100 natural and manmade elements. Atoms of the same element always contain the same number of protons and electrons, but may differ by their number of constituent neutrons. Such atoms of elements having a different number of neutrons are called the *isotopes* of the element. The total number of protons and neutrons in the nucleus of an atom is called its *mass number,* which is used to identify the isotope. For example, the element uranium has 92 protons. Therefore, all isotopes of uranium have 92 protons. Each isotope of uranium is designated by its unique mass number: ^{238}U, the principal naturally occurring isotope of uranium, has 92 protons and 146 neutrons; ^{234}U has 92 protons and 142 neutrons; and ^{235}U has 92 protons and 143 neutrons. Atoms can lose or gain electrons in a process known as *ionization*.

Ionizing radiation has enough energy to free electrons from atoms, creating ions that can cause biological damage. Although it is potentially harmful to human health, ionizing radiation is used in a variety of ways, many of which are familiar to us in our everyday lives. An x-ray machine is one source of ionizing radiation. Likewise, most home smoke detectors use a small source of ionizing radiation to detect smoke particles in the room's air. The two most common mechanisms in which ionizing radiation is generated are the electrical acceleration of atomic particles such as electrons (as in x-ray machines) and the emission of energy from nuclear reactions in atoms. Examples of ionizing radiation include alpha, beta, and gamma radiation.

Alpha radiation occurs when a particle consisting of two protons and two neutrons is emitted from the nucleus of an unstable atom. Alpha particles, because of their relatively large size, do not travel very far and do not penetrate materials well. Alpha particles lose their energy almost as soon as they collide with anything, and therefore a sheet of notebook paper or the skin's surface can be used to block the penetration of most alpha particles. Alpha emitters only become a source of radiation dose after they are inhaled, ingested, or otherwise taken into the body.

Beta radiation occurs when an electron or positron is emitted from an atom. Beta particles are much lighter than alpha particles and therefore can travel faster and farther. Greater precautions must be taken to guard against beta radiation and some shielding is usually recommended to limit exposure to beta radiation. Beta particles can pass through a sheet of paper but can be stopped by a thin sheet of aluminum foil or glass. Most of the radiation dose from beta particles occurs in the first tissue they penetrate, such as the skin, or dose may occur as the result of internal deposition of beta emitters.

Gamma and *x-ray radiation* are known as electromagnetic radiation and are emitted as energy packets called *photons*, similar to light and radio waves, but from a different energy region of the electromagnetic spectrum. Gamma rays and x-rays are the most penetrating type of radiation. Gamma rays are emitted from the nucleus as waves of pure energy, whereas x-rays originate from the electron field surrounding the nucleus. Gamma rays travel at the speed of light, and because they are so penetrating, concrete, lead, or steel is required to shield them. The amount of shielding required, depends upon the energy and intensity of the gamma or x-radiation. For example, to absorb 95 percent of the gamma radiation from a ^{60}Co source, 6 centimeters of lead, 10 centimeters of iron, or 33 centimeters of concrete would be needed.

The neutron is another particle that contributes to radiation exposure, both directly and indirectly. Indirect exposure results from gamma rays and alpha particles that are emitted after neutrons are captured in matter. A neutron has about one quarter of the weight of an alpha particle and can travel 2.5 times faster than an alpha particle. Neutrons are less penetrating than gamma rays because they have mass, but neutrons are more penetrating than beta particles because they are uncharged. They can be shielded effectively by water, graphite, paraffin, or concrete.

Some elements, such as uranium, radium, plutonium, and thorium, share a common characteristic: they are unstable or radioactive. Such radioactive isotopes are called *radionuclides* or *radioisotopes*. As these elements attempt to change into more stable forms, they emit invisible rays of energy or particles at rates which decrease with time. This emission is known as radioactive decay. The time it takes a material to lose half of its original radioactivity is referred to as its half-life. Each radioactive isotope has a characteristic half-life. The half-life may vary from a millionth of a second to millions of years, depending upon the radionuclide. Eventually, the radioactivity will essentially disappear.

As a radioactive element emits radioactivity, it often changes into an entirely different element that may or may not be radioactive. Eventually, however, a stable element is formed. This transformation may require several steps, known as a decay chain. Radium, for example, is a naturally occurring radioactive element with a half-life of 1,622 years. It emits an alpha particle and becomes radon, a radioactive gas with a half-life of only 3.8 days. Radon decays to polonium and, through a series of steps, to bismuth, and ultimately to lead.

Nonionizing radiation bounces off or passes through matter without displacing electrons. Examples include visible light and radio waves. At this time, scientists are unclear as to the effects of nonionizing radiation on human health. In this SPEIS, the term radiation is used to describe ionizing radiation.

C.1.1.2 *How Is Radiation Measured?*

Scientists and engineers use a variety of units to quantify the measurement of radiation. These different units can be used to determine the amount, and intensity of radiation. Radiation is usually measured in *curies*, *rads*, or *rems*. The *curie* describes the activity of radioactive material. One curie is equal to 3.7×10^{10} disintegrations (decays) per second.

Absorbed radiation dose is the amount of energy deposited in a unit mass of material, such as a gram of tissue. Radiation dose is expressed in units of *rad*. One rad is 0.01 joule of energy deposited per kilogram of absorbing material. A joule is a very small amount of energy. For example, a 60-watt light bulb on for about 0.02 seconds would use one joule of energy.

A *rem* is a unit of equivalent dose, which is the absorbed dose modified by a weighting factor to account for the relative biological effectiveness of different types of radiation. The rem is used to measure the effects of radiation on the body. As such, one rem of one type of radiation is presumed to have the same biological effects as one rem of any other type of radiation. This standard allows comparison of the biological effects of different types of radiation. Note that the term millirem (mrem) is also often used. A millirem is one one-thousandth (0.001) of a rem.

C.1.1.3 *How Does Radiation Affect the Human Body?*

Ionizing radiation affects the body through two basic mechanisms. The ionization of atoms can generate chemical changes in body fluids and cellular material. Also, in some cases the amount of energy transferred can be sufficient to actually knock an atom out of its chemical bonds, again resulting in chemical changes. These chemical changes can lead to alteration or disruption of the normal function of the affected area. At low levels of exposure, such as the levels experienced in an occupational or environmental setting, these chemical changes are very small and ineffective. The body has a wide variety of mechanisms that repair the damage induced. However, occasionally, these changes can cause irreparable damage that could ultimately lead to initiation of a cancer, or change to genetic material that could be passed to the next generation. The probability for the occurrence of health effects of this nature depends upon the type and amount of radiation received, and the sensitivity of the part of the body receiving the dose.

At much higher levels of acute whole-body exposure, at least 10–20 times higher than the legal limits for occupational exposures (the limit for annual occupational exposures is 5 rem); damage is much more immediate, direct, and observable. Health effects range from reversible changes in the blood to vomiting, loss of hair, temporary or permanent sterility, and other changes leading ultimately to death at acute exposures (above about 100 times the regulatory limits). In these cases, the severity of the health effect is dependent upon the amount and type of radiation received. Exposures to radiation at these levels are quite rare.

For low levels of radiation exposure, the probabilities for induction of various cancers or genetic effects have been extensively studied by both national and international expert groups. The problem is that the potential for health effects at low levels is extremely difficult to determine without extremely large, well-characterized populations. For example, to get a statistically valid estimate of the number of cancers caused by an external dose equivalent of 1 rem, 10 million people would be required for the test group, with another 10 million for the control group. The risk factors for radiation-induced cancer at low levels of exposure are very small, and it is extremely important to account for the many nonradiation-related mechanisms for cancer induction, such as smoking, diet, lifestyle, chemical exposure, and genetic predisposition. Refer to the Glossary (Chapter 13) for the definition of risk. These multiple factors also make it difficult to establish cause-and-effect relationships that could attribute high or low cancer rates to specific initiators.

The most significant ill-health effects that result from environmental and occupational radiation exposure are cancer fatalities. These ill-health effects are referred to as “latent” cancer fatalities (LCFs) because the cancer may take many years to develop and for death to occur. Furthermore, when death does occur, these ill-health effects may not actually have been the cause of death.

Health impacts from radiation exposure, whether from sources external or internal to the body, generally are identified as somatic (affecting the individual exposed) or genetic (affecting descendants of the exposed individual). Radiation is more likely to produce somatic effects rather than genetic effects. The somatic risks of most importance are the induction of cancers.

For a uniform irradiation of the body, the incidence of cancer varies among organs and tissues. The thyroid and skin demonstrate a greater sensitivity than other organs; however, such cancers also produce relatively low mortality rates because they are relatively amenable to medical treatment.

C.1.1.4 *What Are Some Types of Radiation Dose Measurements?*

The amount of ionizing radiation that the individual receives during the exposure is referred to as *dose*. An external dose is delivered only during the actual time of exposure to the external radiation source. An internal dose, however, continues to be delivered as long as the radioactive material is in the body, although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time. The measurement of radiation dose is called *radiation dosimetry* and is completed by a variety of methods depending upon the characteristics of the incident radiation. External radiation is measured as a value called deep dose equivalent. Internal radiation is measured in terms of the committed effective dose equivalent (CEDE). The sum of the two contributions (deep dose equivalent and CEDE) provides the total dose to the individual, called the total effective dose equivalent (TEDE). Often the radiation dose to a selected group or population is of interest and is referred to as the collective dose equivalent, with the measurement units of *person-rem*.

C.1.1.5 *What Are Some Sources of Radiation?*

Several different sources of radiation have been identified. Most sources are naturally occurring, or background sources, which can be categorized as cosmic, terrestrial, or internal radiation sources. Manmade radiation sources include consumer products, medical sources, and other miscellaneous sources. The average American receives a total of about 360 millirem per year from all sources of radiation, both natural and manmade (ATSDR/CDC 2006).

Cosmic radiation is ionizing radiation resulting from energetically charged particles from space that continuously hit the Earth’s atmosphere. These particles and the secondary particles and photons they create are referred to as cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For example, a person in Denver, CO, is exposed to more cosmic radiation than a person in New Orleans, LA. The average annual dose from cosmic radiation to a person in the United States is about 27 millirem.

Terrestrial radiation is emitted from the radioactive materials in the Earth’s rocks, soils, and minerals. Radon, radon progeny, potassium, isotopes of thorium, and isotopes of uranium are the elements responsible for most terrestrial radiation. The average annual dose from terrestrial radiation is about 28 millirem, but the dose varies geographically across the country. Typically, reported values are about 16 millirem on the Atlantic and Gulf coastal plains and about 63 millirem on the eastern slopes of the Rocky Mountains.

Internal radiation arises from the human body metabolizing natural radioactive material that has entered the body by inhalation, ingestion, or through an open wound. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, bismuth, polonium, potassium, rubidium, and carbon. The major contributors to the annual dose equivalent for internal radioactivity are the short-lived decay products of radon which contribute about 200 millirem per year. The average dose from other internal radionuclides is about 39 millirem per year, most of which results from potassium-40 and polonium-210. Internal exposure can also come from man-made radiation; not only “natural.” (Ingestion is primarily associated with natural radioactive materials [e.g., K-40]. Inhalation is associated with both natural and manmade radioactive materials with the dose delivered to the bronchii of the lungs—without the body metabolizing the material. Open wounds are primarily a concern for internal radiation exposure resulting from occupational settings.)

Consumer products also contain sources of ionizing radiation. In some products, like smoke detectors and airport x-ray machines, the radiation source is essential to the operation of the product. In other products, such as televisions and tobacco products, the radiation occurs incidentally to the product function. The average annual dose from consumer products is about 10 mrem.

Medical source radiation is an important diagnostic tool and is the main source of exposure to the public from manmade radiation. Exposure is deliberate and directly beneficial to the patient exposed. In general, medical exposures from diagnostic or therapeutic x-rays result from beams directed to specific areas of the body. Thus, all body organs generally are not irradiated uniformly. Nuclear medicine examinations and treatments involve the internal administration of radioactive compounds or radiopharmaceuticals by injection, inhalation, consumption, or insertion. Even then, radionuclides are not distributed uniformly throughout the body. Radiation and radioactive materials also are used in the preparation of medical instruments, including the sterilization of heat-sensitive products such as plastic heart valves. Diagnostic x-rays result in an average annual exposure of 39 millirem. Nuclear medical procedures result in an average annual exposure of 14 millirem. It is recognized that the averaging of medical doses over the entire population does not account for the potentially significant variations in annual dose among individuals, where greater doses are received by older or less healthy members of the population.

A few additional sources of radiation contribute minor doses to individuals in the United States. The doses from nuclear fuel cycle facilities, such as uranium mines, mills, and fuel processing plants, nuclear power plants, and transportation routes have been established to be less than 1 mrem per year. Radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive material from U.S. Department of Energy (DOE) facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials contributes less than 1 mrem per year to the average individual dose. Air travel contributes approximately 1 mrem per year to the average dose.

C.1.2 Radioactive Materials in This SPEIS

The release of radiological contaminants into the environment at National Nuclear Security Administration (NNSA) sites occurs as a result of nuclear weapons production, research and development, maintenance, and waste management activities. This section describes the primary types of radioactive sources at NNSA sites, how DOE regulates radiation and radioactive materials, and the data sources and methodologies used to evaluate the potential health effects of radiation exposure to the worker and public.

C.1.2.1 *What Are Some Sources That May Lead to Radiation Exposure?*

Historically, NNSA has conducted many operations that involve the use of uranium, plutonium, tritium, and other radionulides. These have included nuclear material production; recovery and recycle operations; purification processes; and metal forming, machining, and material handling operations. The releases from these operations consisted primarily of particulates, liquids, fumes, and vapors.

Airborne emissions contribute to the potential for radiation dose at, and around, NNSA sites with operations involving radioactive materials. National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations specify that any source that potentially can contribute greater than 0.1 mrem per year TEDE to an offsite individual is to be considered a "major source" and emissions from that source must be continuously sampled. As such, there are a number of process exhaust stacks at NNSA sites that are considered major sources.

In addition to major sources, there are a number of minor sources that have the potential to emit radionuclides to the atmosphere. Minor sources are composed of any ventilation systems or components such as vents, laboratory hoods, room exhausts, and stacks that do not meet the criteria for a major source but are located in or vent from a radiological control area. Emissions from NNSA facility ventilation systems are estimated from radiation control data collected on airborne radioactivity concentrations in the work areas. Other emissions from unmonitored processes and laboratory exhausts are categorized as minor emission sources. Additionally, as explained in Section C.3, accidents can release radionuclides that can result in radiation exposure.

In addition, there are also areas of potential fugitive and diffuse sources at NNSA sites, such as contaminated soils and structures. Diffuse and fugitive sources include any source that is spatially distributed, diffuse in nature, or not emitted with forced air from a stack, vent, or other confined conduit. Radionuclides are transported entirely by diffusion or thermally driven air currents. Typical examples include emissions from building breathing; resuspension of contaminated soils, debris, or other materials; unventilated tanks; ponds, lakes, and streams; wastewater treatment systems; outdoor storage and processing areas; and leaks in piping, valves, or other process equipment.

Liquid discharges are another source of radiation release and exposure. Three types of liquid discharge sources at NNSA sites include treatment facilities, other point- and area-source discharges, and in-stream locations. A radiological monitoring plan is in place at NNSA sites required to address compliance with DOE orders and National Pollutant Discharge Elimination System (NPDES) Permits. Radiological monitoring of storm water is also usually required by the applicable NPDES permits.

C.1.2.2 *How Is Radiation Exposure Regulated?*

The release of radioactive materials and the potential level of radiation doses to workers and the public are regulated by the DOE for its contractor facilities. Under conditions of the *Atomic Energy Act* (as amended by the *Price-Anderson Amendments Act* of 1988), DOE is authorized to establish Federal rules controlling radiological activities at the DOE sites. The act also authorizes DOE to impose civil and criminal penalties for violations of these requirements. Some NNSA activities are also regulated through a DOE Directives System that is contractually enforced.

Occupational radiation protection is regulated by 10 CFR Part 835, Occupational Radiation Protection. DOE has set occupational dose limits for an individual worker at 5,000 millirem per year. NNSA sites have set administrative exposure guidelines at a fraction of this exposure limit to help enforce the goal to manage and control worker exposure to radiation and radioactive material as low as reasonably achievable (ALARA).

Environmental radiation protection is currently regulated contractually with DOE Order 5400.5, Radiation Protection of the Public and the Environment. This Order is applicable to all DOE/NNSA contractor entities managing radioactive materials. This Order sets annual dose standards to members of the public, as a consequence of routine DOE operations, of 100 millirem through all exposure pathways. The Order requires that no member of the public receive an annual dose greater than 10 millirem from the airborne pathway and 4 millirem from ingestion of drinking water. In addition, the dose requirements in the Radionuclide National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP) limit exposure of an individual member of the public to airborne releases of radionuclides to a maximum of 10 millirem per year.

Limits of exposure to members of the public and radiation workers are derived from International Commission on Radiological Protection (ICRP) recommendations. The U.S. Environmental Protection Agency (EPA) uses the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection recommendations and sets specific annual exposure limits (usually less than those specified by the Commission) in *Radiation Protection Guidance to Federal Agencies* documents.

Each regulatory organization then establishes its own set of radiation standards. The various exposure limits set by DOE and the EPA for radiation workers and members of the public are given in Table C.1-1.

Table C.1-1—Exposure Limits for Members of the Public and Radiation Workers

Guidance Criteria (organization)	Public Exposure Limit at the Site Boundary	Worker Exposure Limit
10 CFR Part 835 (DOE)	--	5,000 millirem per year [a]
10 CFR 835.1002 (DOE)	--	1,000 millirem per year [b]
DOE Order 5400.5 (DOE) [c]	10 millirem per year (all air pathways) 4 millirem per year (drinking water pathways) 100 millirem per year (all pathways)	--
40 CFR Part 61 (EPA)	10 millirem per year (all air pathways)	--
40 CFR Part 141 (EPA)	4 millirem per year (drinking water pathways)	--

[a] Although this is a limit (or level) that is enforced by DOE, worker doses must be managed in accordance with as low as is reasonably achievable principles. Refer to footnote b.
[b] This is a control level. It was established by DOE to assist in achieving its goal to maintain radiological doses as low as is reasonably achievable. DOE recommends that facilities adopt a more limiting 500 millirem per year Administrative Control.
[c] Derived from 40 CFR Part 61, 40 CFR Part 141, and 10 CFR Part 20.

C.1.2.3 *Data Sources Used To Evaluate Public Health Consequences From Routine Operations*

Because NNSA operations have the potential to release measurable quantities of radionuclides to the environment that result in exposure to the worker and the public, NNSA conducts environmental surveillance and monitoring activities at its sites. These activities provide data that are used to evaluate radiation exposures that contribute doses to the public. Each year, environmental data from the NNSA sites are collected and analyzed. The results of these environmental monitoring activities are summarized in an *Annual Site Environmental Report* (ASER). The environmental monitoring conducted at most NNSA sites consists of two major activities: effluent monitoring and environmental surveillance.

Effluent monitoring involves the collection and analysis of samples or measurements of liquid (waterborne) and gaseous (airborne) effluents prior to release into the environment. These analytical data provide the basis for the evaluation and official reporting of contaminants, assessment of radiation and chemical exposures to the public, and demonstration of compliance with applicable standards and permit requirements.

Environmental surveillance data provide a direct measurement of contaminants in air, water, groundwater, soil, food, biota, and other media subsequent to effluent release into the environment. These data verify the NNSA site's compliance status and, combined with data from effluent monitoring, allow the determination of chemical and radiation dose and exposure assessment of NNSA operations and effects, if any, on the local environment. The effluent and environmental surveillance data presented in the ASERs were used as the primary source of data for the analysis of radiation exposure to the public for the No Action Alternative.

C.1.3 Methodology for Estimating Radiological Impacts

The public health consequences of radionuclides released to the atmosphere from normal operations at NNSA sites are characterized and calculated in the applicable ASER. Radiation doses are calculated for the maximally exposed individual (MEI) and the entire population residing within 50 miles of the center of the site. In this SPEIS, dose calculations from normal operations were made using the CAP-88 package of computer codes, version 3 (EPA 2008), which was developed under EPA sponsorship to demonstrate compliance with 40 CFR Part 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. This package implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses Regulatory Guide 1.109 (NRC 1977) food-chain models to calculate radionuclide concentrations in foodstuffs (vegetables, meat, and milk) and subsequent intakes by humans.

Meteorological data used in the calculations were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. For occupants of residences, the dose calculations assume that the occupant remained at home (actually, unprotected outside the house) during the entire year and obtained food according to the rural pattern defined in the NESHAP background documents (EPA 1989). This pattern specifies that 70 percent of the vegetables and produce, 44.2 percent of the meat, and 39.9 percent of the milk consumed are produced in the local area (e.g., a home garden). The remaining portion of each food is assumed to be produced within 50 miles of the site. The same assumptions are used for occupants of businesses, but the resulting doses are divided by two to compensate for the fact that businesses are occupied for less than one-half a year and that less than one-half of a worker’s food intake occurs at work. For collective effective dose equivalent (EDE) estimates, production of beef, milk, and crops within 50 miles of the site was calculated using production rates provided with CAP-88.

C.1.4 Risk Characterization and Interpretation of Radiological Data

The Interagency Steering Committee on Radiation Standards (Lawrence 2002) recommended a risk estimator of 6×10^{-4} excess (above those naturally occurring) fatal cancers per person-rem of dose in order to assess health effects to the public and to workers. The probability of an individual worker or member of the public contracting a fatal cancer is 6×10^{-7} per millirem. Radiation exposure can also cause nonfatal cancers and genetic disorders. The probability of incidence of these is one third that of a cancer fatality (Lawrence 2002). In this SPEIS, only estimates of potential fatal cancers are presented.

The radiation exposure risk estimators are denoted as excess because they result in fatal cancers above the naturally occurring annual rate, which is 171.4 per 100,000 population nationally (Ries et al. 2002). Thus, approximately 1,714 fatal cancer deaths per year would be expected to naturally occur in the approximately one million people surrounding an NNSA site. The doses to which they are applied is the EDE, which weights the impacts on particular organs so that the dose from radionuclides that affect different organs can be compared on a similar (effect on whole body) risk basis. All doses in this document are effective dose equivalent unless otherwise noted.

The number of latent cancer fatalities (LCFs) in the general population or in the workforce is determined by multiplying 600 LCFs per million person-rem with the calculated collective population dose (person-rem), or calculated collective workforce dose (person-rem). For example, in a population of 100,000 people exposed only to natural background radiation of 0.3 rem per year, 18 cancer fatalities per year would be inferred to be caused by the radiation (100,000 persons x 0.3 rem per year × 0.0006 cancer fatalities per person-rem = 18 cancer fatalities per year).

Sometimes, calculations of the number of excess cancer fatalities associated with radiation exposure do not yield whole numbers and, especially in environmental applications, may yield numbers less than 1.0. For example, if a population of 100,000 were exposed as above, but to a total dose of only 0.001 rem, the collective dose would be 100 person-rem, and the corresponding estimated number of cancer fatalities would be 0.06 (100,000 persons × 0.001 rem × 0.0006 cancer fatalities/person-rem = 0.06 fatal cancers).

A nonintegral number of cancer fatalities such as 0.06 should be interpreted as a statistical estimate. That is, 0.06 is interpreted as the average number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. In most groups, no person (0 people) would incur a cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, one fatal cancer would result; in exceptionally few groups, two or more fatal cancers would occur. The average number of deaths over all the groups would be 0.06 fatal cancers (just as the average of 0, 0, 0, and 1 is 1/4, or 0.25). The most likely outcome is zero cancer fatalities.

These same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The "number of cancer fatalities" corresponding to a single individual's exposure over a (presumed) 70-year lifetime to 0.3 rem per year is the following:

1 person × 0.3 rem/year × 70 years × 0.0006 cancer fatalities/person-rem = 0.013 cancer fatalities

This could be interpreted that the estimated effect of background radiation exposure on the exposed individual would produce a 1.3 percent chance that the individual might incur a fatal cancer caused by the exposure.

Health effects resulting from exposure to both airborne and waterborne radionuclides may also be evaluated by comparing estimated concentrations to established radionuclide-specific, risk-based concentration values. For example, DOE Order 5400.5 establishes Derived Concentration Guidelines (DCGs) for the inhalation of air and the ingestion of water. The DCG is the concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation) would result in an effective dose equivalent of 100 mrem per year. To ensure that exposure via the drinking water pathway does not exceed four millirem per year, as required by DOE Order 5400.5, four percent of the DCG values are used as comparison values.

Members of the public are assumed to ingest 730 liters per year (2 liters per day) of water or to inhale 8,400 cubic meters per year (23 cubic meters per day) of air. The DCG values are used as reference concentrations for conducting environmental protection programs at DOE sites, as screening values for considering best available technology for treatment of liquid effluents, and for making dose comparisons.

Because fatal cancer is the most probable serious effect of environmental and occupational radiation exposures, this SPEIS presents estimates of LCFs rather than cancer incidence. The numbers of LCFs can be used to compare the risks among the various alternatives. Nonfatal cancers can be estimated by comparing them with the LCF estimates (see Table C.1.4-1).

Table C.1.4-1—Nominal Health Risk Estimators Associated With Exposure to 1 Rem of Ionizing Radiation

Exposed Individual	Fatal Cancer	Nonfatal Cancer
Worker	0.0006	0.0008
Public	0.0006	0.0008

Source: DOE 2002d.

C.1.5 Risk Estimates and Health Effects for Potential Radiation Exposures to Workers

For the purpose of evaluating radiation exposure on an ongoing basis, NNSA workers may be designated as radiation workers, nonradiation workers, or visitors, based upon the potential level of exposure they are expected to encounter in performing their work assignments. For purposes of estimating radiation doses to workers resulting from potential accidents, NNSA looks at involved workers (those workers actually working with radioactive materials) and noninvolved workers (those workers performing other tasks near the involved workers).

Radiation workers have job assignments that place them in proximity to radiation-producing equipment and/or radioactive materials. These workers are trained for unescorted access to radiological areas, and may also be trained radiation workers from another DOE site. These workers are assigned to areas that could potentially contribute to an annual TEDE of more than 100 millirem per year. All trained radiation workers wear dosimeters.

Nonradiation workers are those not currently trained as radiation workers but whose job assignment may require their occasional presence within a radiologically controlled area with an escort. They may be exposed to transient radiation fields as they pass by or through a particular area, but their job assignments are such that annual dose equivalents in excess of 100 millirem are unlikely. Based upon the locations where such personnel work on a daily basis, they may be issued a Personal Nuclear Accident Dosimeter.

Visitors are individuals who are not trained radiation workers and are not expected to receive 100 millirem in a year. Their presence in radiological areas is limited, in terms of time and access. These individuals generally enter specified radiological areas on a limited basis for walk-through or tours with a trained escort. As appropriate, visitors participate in dosimetry monitoring when requested by the hosting division.

C.1.5.1 *NNSA's Radiation Protection Program*

A primary goal of the NNSA Radiation Protection Program is to keep worker exposures to radiation and radioactive material ALARA. Such a program must evaluate both external and internal exposures with the goal to minimize worker radiation dose. The worker radiation dose presented in this SWEIS is the total TEDE incurred by workers as a result of normal operations. This dose is the sum of the external whole body dose, including dose from both photons and neutrons, and internal dose, as required by 10 CFR Part 835. The internal dose is the 50-year CEDE. These values are determined through the NNSA External and Internal Dosimetry Programs.

The External Dosimetry Program at NNSA provides personnel monitoring information necessary to determine the dose equivalent received following external exposure of a person to ionizing radiation. The program is based on the concepts of effective dose equivalent, as described in publications of the ICRP and the International Commission on Radiation Quantities and Units.

Internal dose monitoring programs are conducted at NNSA sites to estimate the quantity and distribution of radionuclides to which a worker may have been exposed. The internal dose monitoring program consists of urinalysis, fecal analysis, lung counting, continuous air monitoring, and retrospective air sampling. Dose assessments are generally based on bioassay data. Bioassay monitoring methods and participation frequencies are required to be established for individuals who are likely to receive intakes that could result in a CEDE that is greater than 100 millirem.

C.2 HAZARDOUS CHEMICAL IMPACTS TO HUMAN HEALTH

C.2.1 Chemicals and Human Health

We use chemicals in our everyday tasks—as pesticides in our gardens, cleaning products in our homes, insulating materials in buildings, and as ingredients in medications. Potentially hazardous chemicals can be found in all of these products, but usually the quantities are not large enough to cause adverse health effects. In contrast to home use, chemicals used in industrial settings are often found in concentrations that may affect the health of individuals in the workplace and in the surrounding community.

For the programmatic alternatives considered in this SPEIS, the chemicals of with the highest hazards were determined to be nitric acid, hydrofluoric acid, formic acid, and chlorine. This determination was based on considerations of vapor pressure, acceptable concentration, and quantity available for release. The following sections describe both the carcinogenic and noncarcinogenic effects of chemicals on the body and how these effects are assessed.

C.2.1.1 *How Do Chemicals Affect the Body?*

Industrial pollutants may be released either intentionally or accidentally to the environment in quantities that could result in health effects to those who come in contact with them. Chemicals that are airborne, or released from stacks and vents, can migrate in the prevailing wind direction for many miles. The public may then be exposed by inhaling chemical vapors or particles of dust contaminated by the pollutants. Additionally, the pollutants may be deposited on the surface soil and biota (plants and animals) and subsequent human exposure could occur. Chemicals may also be released from industries as liquid or solid waste (effluent) and can migrate or be transported from the point of release to a location where exposure could occur.

Exposure is defined as the contact of a person with a chemical or physical agent. For exposure to occur, a chemical source or contaminated media such as soil, water, or air must exist. This source may serve as a point of exposure, or contaminants may be transported away from the source to a point where exposure could occur. In addition, an individual (receptor) must come into either direct or indirect contact with the contaminant. Contact with a chemical can occur through ingestion, inhalation, dermal contact, or external exposure. The exposure may occur over a short (acute or subchronic) or long (chronic) period of time. These methods of contact are typically referred to as exposure routes. The process of assessing all of the methods by which an individual might be exposed to a chemical is referred to as an exposure assessment.

Once an individual is exposed to a hazardous chemical, the body's metabolic processes typically alter the chemical structure of the compound in its efforts to expel the chemical from the system. For example, when compounds are inhaled into the lungs they may be absorbed depending on their size (for particulates) or solubility (for gases and vapors) through the lining of the lungs directly into the blood stream. After absorption, chemicals are distributed in the body and may be metabolized, usually by the liver, into metabolites that may be more toxic than the parent compound. The compound may reach its target tissue, organ, or portion of the body where it will exert an effect, before it is excreted via the kidneys, liver, or lungs. The relative toxicity of a compound is affected by the physical and chemical characteristics of the contaminant, the physical and chemical processes ongoing in the human body and the overall health of an individual. For example, infants, the elderly, and pregnant women are considered more susceptible to certain chemicals.

C.2.2 How Does DOE Regulate Chemical Exposures?

C.2.2.1 *Environmental Protection Standards*

DOE Order 450.1 requires implementation of sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by the DOE operations and by which DOE cost-effectively meets or exceeds compliance with applicable environmental; public health; and resource protection laws, regulations, executive orders, and DOE requirements. The objective is accomplished by implementing Environmental Management Systems (EMSs) at DOE sites. An EMS is a continuing cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental goals. Applicable Federal and State environmental acts/agreements include:

- *Resource Conservation and Recovery Act* (RCRA)
- *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) as amended by the *Superfund Amendments and Reauthorization Act* (SARA)
- Federal Facility Compliance Agreement
- *Endangered Species Act*
- *Safe Drinking Water Act*
- *Clean Water Act* (CWA)(which resulted in the establishment of the NPDES and pretreatment regulations for Publicly-Owned Treatment Works [POTW])
- *Clean Air Act* (CAA) (Title III, Hazardous Air pollutants Rad-NESHAP, Asbestos NESHAP)
- *Toxic Substances Control Act* (TSCA)
- *Federal Insecticide, Fungicide, and Rodenticide Act*

Many of these acts/agreements include environmental standards that must be met to ensure the protection of the public and the environment. Most of the acts/agreements require completed permit applications in order to treat, store, dispose of, or release contaminants to the environment. The applicable environmental standards and reporting requirements are set forth in the issued permits and must be met to ensure compliance.

The *Emergency Planning and Community Right-To-Know Act*, also referred to as SARA Title III, requires reporting of emergency planning information, hazardous chemical inventories, and environmental releases to Federal, State, and local authorities. The annual Toxics Release Inventory report addresses releases of toxic chemicals into the environment, waste management activities, and pollution prevention activities associated with those chemicals.

C.2.2.2 *Regulated Occupational Exposure Limits*

Occupational limits for hazardous chemicals are regulated by the Occupational Safety and Health Administration (OSHA). The permissible exposure limits (PELs) represent the legal concentration levels set by OSHA that are safe for 8-hour exposures without causing noncancer health effects. Other agencies, including the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) provide guidelines. The NIOSH guidelines are Recommended Exposure Limits, and the ACGIH guides are threshold limit values (TLVs). Occupational limits are further defined as time-weighted averages (TWAs), or concentrations for a conventional 8-hour workday and a 40-hour workweek, to which it is believed nearly all workers may be exposed, day after day, without adverse effects. Often ceiling limits, or airborne concentrations that should not be exceeded during any part of the workday, are also specified. In addition to the TWA and ceiling limit, short-term exposure limits may be set. Short-term exposure limits are 15-minute TWA exposures that should not be exceeded at any time during a workday, even if the 8-hour TWA is within limits. OSHA also uses action levels to trigger certain provisions of a standard (e.g., appropriate workplace precautions, training, and medical surveillance) for workers whose exposures could approach the PEL.

C.2.2.3 *Department of Energy Regulation of Worker Safety*

DOE Order 440.1A, Worker Protection Management for DOE Federal and Contractor Employees, regulates the health and safety of workers at all DOE sites. This comprehensive standard directs the contractor facilities to establish the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE Federal and contractor workers with a safe and healthful workplace. Baseline exposure assessments are outlined in this requirement, along with day-by-day health and safety responsibilities.

Industrial hygiene limits for occupational chemical exposures at Federal sites are regulated by 29 CFR Part 1910 and 29 CFR Part 1926, Occupational Safety and Health Standards, including the PELs set by OSHA. DOE requires that all sites comply with the PELs unless a lower limit (more protective) exists in the ACGIH TLVs.

C.3 ACCIDENTS

C.3.1 Introduction

An accident is a sequence of one or more unplanned events with potential unmitigated outcomes that endanger the health and safety of workers and the public. An accident can involve a combined release of energy and hazardous materials (radiological or chemical) that might cause prompt or latent health effects. The sequence usually begins with an initiating event, such as a human error, equipment failure, or earthquake, followed by a succession of other events that could be dependent or independent of the initial event, which dictates the accident's progression and the extent of materials released. Initiating events fall into three categories:

- ***Internal initiators*** normally originate in and around the facility, but are always a result of facility operations. Examples include equipment or structural failures and human errors.
- ***External initiators*** are independent of facility operations and normally originate from outside the facility. Some external initiators affect the ability of the facility to maintain its confinement of hazardous materials because of potential structural damage. Examples include aircraft crashes, vehicle crashes, nearby explosions, and toxic chemical releases at nearby facilities that affect worker performance.
- ***Natural phenomena initiators*** are natural occurrences that are independent of facility operations and occurrences at nearby facilities or operations. Examples include earthquakes, high winds, floods, lightning, wild fires, and snow. Although natural phenomena initiators are independent of external facilities, their occurrence can involve those facilities and compound the progression of the accident.

If an accident were to occur involving the release of radioactive or chemical materials, workers, members of the public, and the environment would be at risk. Workers in the facility where the accident occurs would be particularly vulnerable to the effects of the accident because of their location. The offsite public would also be at risk of exposure to the extent that meteorological conditions exist for the atmospheric dispersion of released hazardous materials. Using approved computer models, the dispersion of released hazardous materials and their effects are predicted. However, prediction of latent potential health effects becomes increasingly difficult to quantify for facility workers as the distance between the accident location and the worker decreases. This is because the individual worker exposure cannot be precisely defined with respect to the presence of shielding and other protective features. The worker also may be injured or killed by physical effects of the accident itself.

The potential for facility accidents and the magnitudes of their consequences are important factors in evaluating the alternatives addressed in this SPEIS. The health risk issues are twofold:

- Whether accidents at any of the individual facilities (or reasonable combinations thereof) pose unacceptable health risks to workers or the general public; and
- Whether alternative locations for facilities (or reasonable combinations thereof) can provide lesser public or worker health risks. These lesser risks may arise either from a greater isolation of the site from the public or from a reduced frequency of such external accident initiators as seismic events.

Guidance for implementing Council on Environmental Quality (CEQ) regulation, 40 Code of Federal Regulations 1502.22, as amended (51 FR 15618), requires the evaluation of impacts which have low probability of occurrence but high consequences if they do occur; thus, facility accidents must be addressed to the extent feasible in this SPEIS. Further, public comments received during the scoping process clearly indicated the public's concern with facility safety and consequent health risks and the need to address these concerns in the decision-making process.

For the No Action Alternative, potential accidents are defined in existing facility documentation, such as safety analysis reports, hazards assessment documents, NEPA documents, and probabilistic risk assessments. The accidents include radiological and chemical accidents that produce high consequences but have a low likelihood of occurrence, and a spectrum of other accidents that have a higher likelihood of occurrence and lesser consequences. The data in these documents include accident scenarios, probabilities, materials at risk, source terms (quantities of hazardous materials released to the environment), and consequences.

For new, modified, or upgraded NNSA facilities, the identification of accident scenarios and associated data would normally be a product of safety analysis reports performed on completed facility designs. However, facility designs have not been completed for the facility alternatives analyzed in the programmatic portion of this SPEIS. Accordingly, the accident information developed for this SPEIS was developed based upon existing information for similar facilities. The first step in the process was to review all of the potential types of facilities and processes that could be associated with the Consolidated Plutonium Center (CPC), Consolidated Uranium Center (CUC), and Assembly/Disassembly/High Explosives (A/D/HE) Center, with emphasis on building hazard classification and radionuclide inventories (including type, quantity, and physical form) and storage and use conditions. First, administrative buildings without radioactive materials were excluded. Then, buildings ranked as low hazard and those without radioactive materials were eliminated from consideration. The potential offsite consequences of facilities screened out would be well bounded by a nuclear facility's bounding accident scenarios.

The next step in the selection process was to identify the most current documentation describing/quantifying the hazards associated with each facility's operation. Current safety documentation, which is either classified or contains Unclassified Controlled Nuclear Information that is not releasable to the general public, was obtained for these facilities, and reviewed to determine a reasonable range of bounding accidents for the CPC, CUC, and A/D/HE Center. Documents such as those shown in Table C.3-1 were reviewed for applicable accident scenarios and data.

The process sought to identify a bounding accident in each of several classes of events (e.g., fire, explosion, spill, mechanical, criticality, natural phenomena initiators, and external initiators) applicable to the alternative. The process also sought to identify bounding accidents over the spectrum of high to low probability of occurrence in order to include high-consequence/low-probability and low-consequence/high-probability accidents. These accidents are generally referred to as beyond evaluation basis accidents and evaluation basis accidents, respectively.

Beyond evaluation basis accidents are generally in the probability of occurrence range of 1×10^{-7} to 10^{-6} per year, and evaluation basis accidents generally have a probability of occurrence greater than 1×10^{-6} per year. These two designations are used only if formal SARs have not been prepared. In cases where Safety Analyses Reports (SARs) have been prepared, they are the source documents for two equivalent designations "beyond design basis accidents" and "design basis accidents."

Table C.3-1—Source Documents Reviewed for Applicable Accident Scenarios

Title	Date
"The Continued Operation of the Pantex Plant & Associated Storage of Weapons Components" **Unclassified Controlled Nuclear Information**	Sept. 1995
"CMR Facility (SM-29) Final Safety Analysis Report" **Unclassified Controlled Nuclear Information**	Feb. 1994
Executive Summary—"Hazards Analysis of the Los Alamos National Laboratory Plutonium Facility (TA-55)" **Unclassified Controlled Nuclear Information**	July 13, 1995
Stockpile Stewardship and Management/PEIS "Alternative Report for Pit Manufacturing at SRS" **Unclassified Controlled Nuclear Information**	Sept. 1, 1995
Draft Safety Analysis Report for "The Device Assembly Facility at the Nevada Test Site" **Unclassified Controlled Nuclear Information**	Mar. 1995
"U.S. Department of Energy Defense Programs Safety Survey Report" Volume III: Appendix B—Uranium Facilities **Unclassified Controlled Nuclear Information**	Nov. 1993
"U.S. Department of Energy Defense Programs Safety Survey Report" Volume I: Main Report **Unclassified Controlled Nuclear Information**	Nov. 1993
"U.S. Department of Energy Defense Programs Safety Survey Report" Volume II: Appendix A—Plutonium Facilities **Unclassified Controlled Nuclear Information**	Nov. 1993
"U.S. Department Of Energy Defense Programs Safety Survey Report" Volume VI: Appendix E—Spent-fuel Handling Facilities **Unclassified Controlled Nuclear Information**	Nov. 1993
"TA-55 Final Safety Analysis Report" Volume I **Unclassified Controlled Nuclear Information**	July 13, 1995
"TA-55 Final Safety Analysis Report" Volume II **Unclassified Controlled Nuclear Information**	July 13, 1995
"TA-55 Hazard Analysis" **Unclassified Controlled Nuclear Information**	July 13, 1995
"Nuclear Explosive Facilities Final Safety Analysis Report Nuclear Explosive Cells Module" (Buildings 12-44 Cells 1-6, 12-85, 12-96, and 12-98) **Unclassified Controlled Nuclear Information**	July 1995
"Nuclear Explosive Facilities Final Safety Analysis Report Nuclear Explosive Cells Module" (Buildings 12-44 Cells 1-6, 12-85, 12-96, and 12-98) **Unclassified Controlled Nuclear Information**	July 1995
"Nuclear Explosive Facilities Final Safety Analysis Report Nuclear Explosive Bays Module" (Buildings 12-64, 12-84, 12-99, and 12-104) **Unclassified Controlled Nuclear Information**	Dec. 1994
"Nuclear Explosive Facilities Final Safety Analysis Report Nuclear Explosive Bays Module" (Buildings 12-64, 12-84, 12-99, and 12-104) **Unclassified Controlled Nuclear Information**	Dec. 1994
"Preliminary Safety Analysis Report Special Nuclear Materials Component Staging Facility" **Unclassified Controlled Nuclear Information**	Apr. 1989
"Safety Analysis Report - On-Site Transportation" **Unclassified Controlled Nuclear Information**	Sept. 1995
Appendix 11-K—Release Fraction Data, Appendix 11-J - Consequence Equations Used in the Accident Analysis, Appendix 11-F - Seismic Accident Analysis, Appendix 11-E - Derivation of Data Values Used in the Accident Analysis **Unclassified Controlled Nuclear Information**	Feb. 1994
Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management (DOE 1996d)	Sept. 1996
Site-Wide Environmental Impact Statement for Continued Operation of the Los Alamos National Laboratory (LANL 1999)	Jan. 1999

Table C.3-1—Source Documents Reviewed for Applicable Accident Scenarios (continued)

Title	Date
Final Supplement Analysis for Pit Manufacturing Facilities at Los Alamos National Laboratory, Stockpile Stewardship and Management Programmatic Environmental Impact Statement (LANL 1999b	Sept. 1999
Topical Report—Supporting Documentation for the Accident Impacts Presented in the Stockpile Stewardship and Management Programmatic Environmental Impact Statement (Maltese et al., 1996)	June 1996
Modern Pit Facility Pre-Conceptual Design Radiological Hazards Evaluation	Jan. 2002
Safety Analysis Report for the 9215 Complex, Y/MA-7886, Rev. 4, Effective 12/08/2005 **Unclassified Controlled Nuclear Information**	Dec. 2005
Safety Analysis Report for the 9204-2E Facility, Y/SAR-003, Rev. 4, Effective 12/01/2005 **Unclassified Controlled Nuclear Information**	Dec. 2005
Safety Analysis Report for the 9204-2 Facility, Y/SM-SAR-005, Rev. 4, Effective 12/20/2005 **Unclassified Controlled Nuclear Information**	Dec. 2005
Safety Analysis Report for the 9204-4 Facility, Y/SAR-004, Rev. 4, Effective 02/24/2005 **Unclassified Controlled Nuclear Information**	Feb. 2005
Safety Analysis Report for the Nuclear Material Safeguarded Shipping and Storage Facility, Y/SAR-10, Rev. 5, Effective 12/21/2005 **Unclassified Controlled Nuclear Information**	Dec. 2005
Preliminary Documented Safety Analysis for the Highly Enriched Uranium Materials Facility, Y/HEU-0091 Rev. 0, 08/17/04 **Unclassified Controlled Nuclear Information**	Aug. 2004
Basis for Interim Operation for the Enriched Uranium Operations Complex, Y/MA-7254, Rev. 18, Effective 09/23/2004 **Unclassified Controlled Nuclear Information**	Sept. 2004
Safety Analysis Report for 9212 Complex, Y/MA-7926, Rev. 1, 11/18/05 (Approved not yet effective) **Unclassified Controlled Nuclear Information**	Nov. 2005
Safety Analysis Report for Building 9995, Y/ENG/SAR-79, Rev. 4, 05/20/2005, Effective 06/22/2005 **Unclassified Controlled Nuclear Information**	May 2005
Safety Analysis Report for Building 9201-5/5E, Y/NA-1836, Rev. 3, 05/16/2005, Effective 06/30/2005 **Unclassified Controlled Nuclear Information**	May 2005
Safety Analysis Report for Buildings 9201-5N/5W, Y/NA-1839, Rev. 3, 05/16/2005, Effective 06/30/2005 **Unclassified Controlled Nuclear Information**	May 2005
Basis for Interim Operations for the Pantex Plant, Amarillo, Texas, Pantex Plant, June 1995 (Pantex 1995j). **Unclassified Controlled Nuclear Information**	June 1995
Basis for Interim Operations for the Non-Nuclear Facilities Amarillo, Texas, Pantex Plant, September 1995 (Pantex 1995). **Unclassified Controlled Nuclear Information**	Sept. 1995
Chemical High Explosives Hazards Assessment for the Pantex Plant, Jacobs Engineering, October 1993 (Jacobs 1993a). **Unclassified Controlled Nuclear Information**	Oct. 1993
Natural Phenomena Hazards Assessment for the Pantex Plant Amarillo, Texas, Jacobs Engineering, October 1993 (Jacobs 1993). **Unclassified Controlled Nuclear Information**	Oct. 1993
Recalculation of Potential Deposition Levels and Dose Exposure Levels for the Pantex Radiological Hazards Assessment, Jacobs Engineering, October 1993 Jacobs 1993b). **Unclassified Controlled Nuclear Information**	Oct. 1993
Pantex Plant, *Safety Information Document*, prepared for the U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, NM, September 1996 (Pantex 1996a). **Unclassified Controlled Nuclear Information**	Sept. 1996

For each facility, applicable accidents were analyzed to estimate risk (i.e., mathematical product of an accident's probability of occurrence and the accident's consequences) and consequences (e.g., LCF) to a noninvolved worker, an MEI (a hypothetical member of the public located at the closest site boundary), and the surrounding population within 50 miles of the site. This analysis considers the potential differences in likelihood of accident initiators at specific sites (e.g., beyond design basis seismic events, and so forth). The likelihood and consequences of accidents (which are site dependent) are analyzed at each of the sites where a particular facility may be located. This calculation reflects the effects of such site parameters as population size and distribution, meteorology, and distance to the site boundary. Based on this process, the following reference report was prepared: *Topical Report—Supporting Documentation for the Accident Impacts Presented in the Complex Transformation Supplemental Programmatic Environmental Impact Statement* (Tetra Tech 2008).

The accidents described in Sections C.4 through C.6 were selected from a wide spectrum of potential accident scenarios. The selection process, screening criteria used, and conservative estimates of material at risk and source term ensure that the accidents chosen for evaluation in this SPEIS bound the impacts of all reasonably foreseeable accidents that could occur under an alternative. Thus, in the event that any other accident that was not evaluated in this SPEIS were to occur, its impacts on workers and the public would be expected to be within the range of the impacts evaluated. All accidents are assumed to result in ground-level, one-hour duration releases unless indicated otherwise. All releases are assumed neutrally buoyant except the uranium operations aircraft crash, for which the added heat was taken as 4.6 megawatts, the value used in the Lawrence Livermore Continued Operations SWEIS (DOE 2005a).

Of particular interest are the uncertainties in the estimates of cancer fatalities from exposure to radioactive materials. The numerical values of the health risk estimators used in this SPEIS were obtained by linear extrapolation from the nominal risk estimate for lifetime total cancer mortality resulting from exposures of 10 rad. There is uncertainty about cancer risk in the low-dose region and the possibility of no risk cannot be excluded. Because the health risk estimators are multiplied by conservatively calculated radiological doses to predict fatal cancer risks, the fatal cancer values presented in this EIS are expected to be overestimates.

For the purposes of this EIS, the impacts calculated from the linear model are treated as an upper-bound case, consistent with the widely used methodologies for quantifying radiogenic health impacts. This does not imply that health effects are expected. Moreover, in cases where the upper-bound estimators predict a number of LCFs greater than one, this does not imply that the LCF risk can be determined for a specific individual.

C.3.1.1 *Assessment of Vulnerability to Terrorist Threats*

The methodology for the assessment of vulnerability to terrorist threats is discussed in Appendix B, Section B.12.3.

C.3.2 Safety Design Process

Subsequent to this SPEIS, evaluation of the specific benefits achieved would be presented for each new facility in a Hazards Analysis Document. This document would identify and estimate the effects of all major hazards that have the potential to impact the environment, workers, and the public, and would be issued in conjunction with the Conceptual Design Package. Additional accident analyses for identified major hazards would be provided in a Preliminary SAR to be issued during the period of Definitive Design (Title II) Review. A Final SAR would be prepared during the construction period and issued before testing begins as final documented evidence that the new facility can be operated in a manner that does not present any undue risk to the health and safety of workers and the public.

One of the major design goals for any Complex Transformation facility is to achieve a reduced risk to workers and the public relative to that associated with similar facilities in the existing Nuclear Weapons Complex. Any new NNSA facilities would be designed to comply with current Federal, State, and local laws; DOE orders; and industrial codes and standards. As a result, a facility will be provided that is highly resistant to the effects of natural phenomena, including earthquake, flood, tornado, high wind, as well as credible events appropriate to the site, such as fire, explosions, and manmade threats. The facilities would be designed to maintain their continuing structural integrity in the event of any credible accident or event, including an aircraft crash, if credible at these sites.

The design process for new and modified facilities would comply with the requirements for safety analysis and evaluation in DOE Order 430.1B, Real Property Asset Management, assessment is required to be an integral part of the design process to ensure compliance with all DOE safety criteria by the time that the facilities are constructed and in operation.

For new facilities, the safety analysis process begins early in conceptual design by identifying hazards with the potential to produce unacceptable safety consequences to workers or the public. As the design develops, failure mode and effects analyses are performed to identify events that have the potential to release hazardous material. The kinds of events considered include equipment failure, spills, human error, fire and explosions, criticality, earthquake, electrical storms, tornado, flood, and aircraft crash. These postulated events become focal points for design changes or improvements to prevent unacceptable accidents. These analyses continue as the design progresses to assess the need for safety equipment and to assess the performance of this equipment in accident mitigation. Eventually, the safety analyses are formally documented in an SAR and/or in a probabilistic risk assessment. The probabilistic risk assessment documents the estimated frequency and consequence for an entire spectrum of accidents and helps to identify design improvements that could make meaningful safety improvements.

The first SAR is completed at the conclusion of conceptual design and includes identification of hazards and some limited assessment of a few enveloping design basis accidents. This analysis includes deterministic safety analysis and failure modes and effects analysis of major systems. A detailed, comprehensive Preliminary SAR is completed during preliminary design and provides a broad assessment of the range of design basis accident scenarios and the performance of equipment provided in the facility specifically for accident consequence mitigation. A limited probability risk assessment may be included in that analysis.

The SAR continues to be developed during detailed design. The safety review of this report and any supporting probabilistic risk assessment is completed and safety issues resolved before the facility construction is initiated. The Final SAR documents safety-related design changes during construction and the impact of those changes on the safety assessment. It also includes the results of any safety-related research and development that has been performed to support the safety assessment of the facility.

C.3.3 Consequence Analysis Methodology

The MELCOR Accident Consequence Code System (MACCS) was used to estimate the radiological consequences of all stockpile stewardship and management facilities for all accidents. MACCS2 is a DOE/Nuclear Regulatory Commission (DOE/NRC)-sponsored computer code that has been widely used in support of probabilistic risk assessments for the nuclear power industry and in support of safety and NEPA documentation for facilities throughout the DOE Complex. A brief description of MAACS follows. A detailed description of the MACCS model is available in a three-volume report: *MELCOR Accident Consequence Code System* (MACCS) (NUREG 1990).

MACCS models the offsite consequences of an accident that releases a plume of radioactive materials to the atmosphere. Should such an accidental release occur, the radioactive gases and aerosols in the plume would be transported by the prevailing wind while dispersing in the atmosphere. The environment would be contaminated by radioactive materials deposited from the plume, and the population would be exposed to radiation. The objectives of a MACCS calculation are to estimate the range and probability of the health induced by the radiation exposures not avoided by protective actions.

The MACCS2 code uses three distinct modules for consequence calculations: The ATMOS module performs atmospheric transport calculations, including dispersion, deposition, and decay. The EARLY module performs exposure calculations corresponding to the period immediately following the release; this module also includes the capability to simulate evacuation from areas surrounding the release. The EARLY module exposure pathways include inhalation, cloudshine, and groundshine. The CHRONC module considers the time period following the early phase (i.e., after the plume has passed). CHRONC exposure pathways include groundshine, resuspension inhalation, and ingestion of contaminated food and water. Land use interdiction (e.g., decontamination) can be simulated in this module. Other supporting input files include a meteorological data file and a site data file containing distributions of the population and agriculture surrounding the release site.

In order to understand MACCS, one must understand its two essential elements: the time scale after an accident is divided into various "phases"; and the region surrounding the facility is divided into a polar-coordinate grid. The time scale after the accident is divided into three phases: emergency phase, intermediate phase, and long-term phase. The emergency phase begins immediately after the accident and could last up to seven days. In this period, the exposure of the population to both radioactive clouds and contaminated ground is modeled. Various protective measures can be specified for this phase, including evacuation, sheltering, and dose-dependent relocation.

The intermediate phase can be used to represent a period in which evaluations are performed and decisions are made regarding the type of protective measure actions that need to be taken. In this period, the radioactive clouds are assumed to be gone, and the only exposure pathways are those from the contaminated ground. The only protective measure that can be taken during this period is temporary relocation.

The long-term phase represents all time subsequent to the intermediate phase. The only exposure pathways considered here are those resulting from the contaminated ground. A variety of protective measures can be taken in the long-term phase in order to reduce doses to acceptable levels: decontamination, interdiction, and condemnation of property.

As implemented, the MACCS2 model evaluates doses due to inhalation of airborne material, as well as external exposure to the passing plume. This represents the major portion of the dose that an individual would receive because of a facility accident. The longer-term effects of radioactive material deposited on the ground after a postulated accident, including the resuspension and subsequent inhalation of radioactive material and the ingestion of contaminated crops, were not modeled for this SPEIS because these pathways have been studied and found to contribute less significantly to the dosage than the inhalation of radioactive material in the passing plume; they are also controllable through interdiction. Instead, the deposition velocity of the radioactive material was set to zero, so that material that might otherwise be deposited on surfaces remained airborne and available for inhalation. Thus, the method used in this SPEIS is conservative compared with dose results that would be obtained if deposition and resuspension were taken into account.

The source terms were handled by the code by considering the materials at risk (MAR) as the inventory. The release fraction of each scenario was then the product of the various factors (damage ratio [DR], airborne release fraction [ARF], respirable fraction [RF], and leak path factor [LPF]) that describe the material available to actually impact a receptor. The meteorological data consisted of sequential hourly wind speed, wind direction, stability class, and precipitation for one year.

Each four-hour period of the annual meteorological site specific data set for each site was randomly sampled, assuring a good representation of the entire meteorological data set. The results from each of these samples were then ranked and combined (according to their frequency of occurrence) and a distribution of results is presented by the code. This distribution includes statistics such as 95th percentile, 50th percentile, and mean dose. The latter is presented in this SPEIS.

Because of assumptions used in this SPEIS analysis, not all of the code’s capabilities were used. For example, it was conservatively assumed that no special actions would be taken to avoid or mitigate exposure to the general population following an accidental release of radionuclides.

Population and individual doses were statistically sampled by assuming an equally likely accident start time during any hour of the year. MEI and noninvolved worker doses were calculated using conservative assumptions, such as the wind blowing toward the MEI and locating the receptor along the plume centerline. The doses (50-year committed EDE) were converted into LCFs using the factor of 6×10^{-4} LCFs per person-rem for both members of the public and workers (DOE 2002d); calculated LCFs were doubled for individual doses greater than 20 rem (NCRP 1993). The MEI and noninvolved worker are assumed to be exposed for the duration of the release; they or DOE would take protective or mitigative actions thereafter if required by the size of the release. Exposure to the general population continues after the release as a result of resuspension and inhalation, external exposure and ingestion of deposited radionuclides.

C.3.3.1 *Analysis Conservatism and Uncertainty*

The analysis of accidents is based on calculations relevant to hypothetical sequences of events and models of their potential impacts. The models provide estimates of the frequencies, source terms, pathways for dispersion, exposures, and the effects on human health and the environment as realistic as possible within the scope of the analysis. In many cases, the scarcity of experience with the postulated accidents leads to uncertainty in the calculation of the consequences and frequencies. This fact has promoted the use of models or input values that yield conservative estimates of consequences and frequency. Additionally, since no credit is taken for safety systems that may function during an event, these events do not represent expected conditions within the facility at any point in its lifetime.

Due to the layers of conservatism built into the accident analysis for the spectrum of postulated accidents, the estimated consequences and risks to the public represent the upper limit for the individual classes of accidents. A conservative approach is appropriate and standard practice for analyses of this type, which involve high degrees of uncertainty associated with analytical factors such as accident frequency, MAR, and LPF.

C.3.3.2 *Mitigation Measures*

Mitigations to exposure and therefore mitigations to dose that would affect the postulated results of the accident scenarios are discussed below. In general, no mitigation was assumed for emergency response in the consequence analysis.

C.3.3.2.1 Emergency Response and Protective Actions

NNSA sites have detailed plans for responding to accidents of the type described in this SPEIS, and the response activities would be closely coordinated with those of local communities. NNSA personnel are trained and drilled in the protective actions to be taken if a release of radioactive or otherwise toxic material occurs. The underlying principle for the protective action guides (PAGs) is that under emergency conditions all reasonable measures should be taken to minimize the radiation exposure of the general public and emergency workers. In the absence of significant constraints, protective actions could be implemented when projected doses are lower than the ranges given in the PAGs. No credit was taken for emergency response and protective actions in the consequence analysis.

C.3.3.2.2 High Efficiency Particulate Air Filtration

In all areas where unconfined plutonium or other radioactive materials can be handled and can exist in a dispersible form, high-efficiency particulate air (HEPA) filters provide a final barrier against the inadvertent release of radioactive aerosols into the outside environment. However, these filters would not trap volatile fission products such as the noble gases and iodine; such gases would be released into the outside environment.

HEPA filter efficiencies are 99.99 percent or greater with the minimum efficiency of 99.97 percent for 0.3-micron particles, the size most easily passed by the filter. To maximize containment of particles and provide redundancy, two HEPA filters in series would be used, as is the normal operational procedure at such NNSA facilities. Additional HEPA filtration would be used, as required, to ensure compliance with regulatory requirements. These HEPA filters are protected by building design features against the consequences of an earthquake or fire. Credit was taken for filtration in the consequence analysis when ventilation and building containment were shown by analysis to survive during the accident.

C.3.3.3 *Chemical Releases*

Consequences of accidental chemical releases were determined using the Aerial Location of Hazardous Atmospheres (ALOHA) computer code (EPA 1999b). ALOHA is an EPA/National Oceanic and Atmospheric Administration (NOAA)-sponsored computer code that has been widely used in support of chemical accident responses and also in support of safety and NEPA documentation for DOE facilities.

The ALOHA code is a deterministic representation of atmospheric releases of toxic and hazardous chemicals. The code can predict the rate at which chemical vapors escape (e.g., from puddles or leaking tanks) into the atmosphere; a specified direct release rate is also an option. Either of two dispersion algorithms is applied by the code, depending on whether the release is neutrally buoyant or heavier than air. The former is modeled similarly to radioactive releases in that the plume is assumed to advect with the wind velocity. The latter considers the initial slumping and spreading of the release because of its density. As a heavier-than-air release becomes more dilute, its behavior tends towards that of a neutrally buoyant release.

The ALOHA code uses a constant set of meteorological conditions (e.g., wind speed, stability class) to determine the downwind atmospheric concentrations. The sequential meteorological data sets used for the radiological accident analyses were re-ordered from high to low dispersion by applying a Gaussian dispersion model (such as that used by ALOHA) to the closest site boundary at each site. The median set of hourly conditions for each site (i.e., mean wind speed and mean stability) was used for the analysis; this is roughly equivalent to the conditions corresponding to the mean radiological dose estimates of MACCS2.

In addition to the source term and downwind concentration calculations, ALOHA allows for the specification of concentration limits for the purpose of consequence assessment (e.g., assessment of human health risks from contaminant plume exposure). ALOHA refers to these concentration limits as level-of-concern (LOC) concentrations. Safety analysis work uses the Emergency Response Planning Guidelines (ERPGs) and Temporary Emergency Exposure Limits (TEELs) for assessing human health effects for both facility workers and the general public. While ERPGs and TEELs are not explicitly a part of the ALOHA chemical database, ALOHA allows the user to input any value, including an ERPG or TEEL value, as the LOC concentration. The LOC value is superimposed on the ALOHA-generated plot of downwind concentration as a function of time to facilitate comparison. In addition, ALOHA will generate a footprint that shows the area (in terms of longitudinal and lateral boundaries) where the ground-level concentration reached or exceeded the LOC during puff or plume passage (the footprint is most useful for emergency response applications).

ERPG Definitions

ERPG-1 *is the maximum airborne concentration below which nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.*

ERPG-2 *is the maximum airborne concentration below which nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.*

ERPG-3 *is the maximum airborne concentration below which nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.*

ALOHA contains physical and toxicological properties for the chemical spills included in the EIS and for approximately 1,000 additional chemicals. The physical properties were used to determine which of the dispersion models and accompanying parameters were applied. The toxicological properties were used to determine the levels of concern. Atmospheric concentrations at which health effects are of concern (e.g., ERPG-2) are used to define the footprint of concern because the meteorological conditions specified do not account for wind direction (i.e., it is not known a priori in which direction the wind would be blowing in the event of an accident) the areas of concern are defined by a circle of radius equivalent to the downwind distance at which the concentration decreases to levels less than the level of concern. The fraction of the area of concern actually exposed to the concentration of concern (footprint area/circle area) was noted. In addition, the concentration at 1,000 meters (3,281 feet) (potential exposure to a noninvolved worker) and at the nearest site boundary distance (exposure to maximum exposed offsite individual) are calculated and presented.

C.4 RADIOLOGICAL ACCIDENT SCENARIOS—CPC

CPC-related facility radiological and chemical accidents are described in Tables C.4-1 and C.4-2. These tables also identify the estimated maximum MAR and source term and accident frequency. Section C.5 provides additional data on release fractions such as damage ratio, leak path factor, and estimated respirable release fraction (RRF) for each postulated accident. The RRF is the mathematical product of the ARF and the RF calculated by the equation RRF = ARF × RF (Tetra Tech 2008).

C.4.1 Postulated Accidents

The accident scenarios shown in Tables C.4-1 and C.4-2 cover the types of hazardous situations appropriate for the Complex Transformation SPEIS. The list includes fires, spills, criticality and explosions events, site-specific externally initiated events, and natural phenomena events. For radiological accidents, the material at risk is plutonium and the predominant form of exposure is through inhalation. For radiological accidents, the material at risk is plutonium and the predominant form of exposure is through inhalation. The list also includes the potential release of toxic chemicals used in CPC processes. The accidents listed in this section were selected from a wide spectrum of accidents described in the *Topical Report—Supporting Documentation for the Accident Impacts Presented in the Complex Transformation Supplemental Programmatic Environmental Impact Statement* (Tetra Tech 2008).

The results of the accident analysis indicate potential consequences that exceed the DOE exposure guidelines of 25 rem for a member of the public at the nearest site boundary. The analyses in these cases for NEPA purposes are based on unmitigated releases of radioactive material to select a site for the CPC. Following the Record of Decision (ROD) and selection of a site, additional NEPA action would be taken that would identify specific mitigating features that would be incorporated in the CPC design to ensure compliance with DOE exposure guidelines. These could include procedural and equipment safety features, additional HEPA filtration systems, and other design features that would protect radioactive materials from accident conditions and contain any material that might be released. DOE would prepare safety analysis documentation such as a safety analysis report to further ensure that DOE exposure guidelines would not be exceeded. The results of the safety analysis report are reflected in facility and equipment design and defines an operating envelope and procedures to ensure public and worker safety. Specific mitigation measures would be incorporated into a CPC design and operating procedures to ensure that consequences would not exceed the DOE exposure guidelines of 25 rem for a member of the public at the nearest site boundary for any of the site alternatives.

The accident source terms shown in Tables C.4–1 and C.4-2 indicate the quantity of radioactive and chemical material released to the environment with a potential for harm to the public and onsite workers. The radiological source terms are calculated by the equation:

Source Term = MAR × ARF × RF × DR × LPF, where:

MAR. The amount and form of radioactive material at risk of being released to the environment under accident conditions.

ARF. The airborne release fraction reflecting the fraction of damaged MAR that becomes airborne as a result of the accident.

RF. The respirable fraction reflecting the fraction of airborne radioactive material that is small enough to be inhaled by a human.

DR. The damage ratio reflecting the fraction of MAR that is damaged in the accident and available for release to the environment.

LPF. The leak path factor reflecting the fraction of respirable radioactive material that has a pathway out of the facility for dispersal in the environment.

The accident source terms for chemical accidents are shown in Table C.4-2. The impacts of chemical accidents are measured in terms of ERPG-2 and ERPG-3 concentration limits established by the American Industrial Hygiene Association. ERPG-2 is defined as the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective actions. ERPG-3 is defined as the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

Beyond evaluation basis earthquake with fire. The earthquake accident scenario postulates a seismic event and seismically induced failure of interior nonstructural walls. The collapsed walls cause a loss of confinement and a potential release of materials in multiple areas in the facility. Combustible materials in the area are ignited, and the resulting fire propagates to multiple areas of the facility, including storage vaults in three buildings containing the largest quantity of plutonium metal. The MAR for the 125 pits per year (ppy) production case includes 16,929 kilograms (37,322 pounds) metal, 36 kilograms (79 pounds) powder, and 24 kilograms (53 pounds) solution. The bounding seismic accident with fire conservatively assumes a damage ratio (DR) = 1.0 resulting in all of the MAR to be affected by the fire. The collapsed walls cause a loss of confinement resulting in an assumed leak path factor (LPF) = 1.0. The airborne respirable release fraction is estimated to be ARF × RF = 2.5×10^{-4} (metal), 6×10^{-5} (oxide), and 2×10^{-3} (solution). No credit is taken for the mitigating effects of safety systems, fire suppression efforts and equipment, plutonium cladding, the shipping containers, or the final building state (building collapse and rubble bed). The resulting source term for the 125 ppy case is 4.23 kilograms (9.3 pounds) of plutonium metal, 0.0021 kilograms (0.0046 pounds) of plutonium oxide, and 0.048 kilograms (0.11 pounds) of plutonium solution. The accident frequency is estimated to be in the range of from 1×10^{-6} to 1×10^{-5} per year. For the purpose of risk calculations, a conservative frequency of 1×10^{-5} per year is assumed (Tetra Tech 2008).

Fire in a single building. A fire is postulated to start within a glovebox, processing room, or storage vault. Possible causes of the fire include an electrical short, equipment failure, welding equipment, or human error. The fire propagates to multiple areas of the facility involving the largest quantities of plutonium metal. The material at risk is a maximum 7,685 kilograms (16,943 pounds) of plutonium metal for the 125 ppy. The bounding fire accident conservatively assumes a DR = 1.0 resulting in all of the MAR to be affected by the fire. No credit is taken for safety systems, building confinement, or filtration resulting in an assumed LPF = 1.0. The airborne respirable release fraction is estimated to be ARF × RF = 2.5×10^{-4}. No credit is taken for the mitigating effects of fire suppression efforts and equipment, plutonium cladding, or the shipping containers. The resulting source term is a ground level, thermal release of 1.92 kilograms (4.23 pounds) of plutonium. The accident frequency is estimated to be in the range of from 1×10^{-6} to 1×10^{-4} per year. For the purpose of risk calculations, a conservative frequency of 1×10^{-4} per year is assumed (Tetra Tech 2008).

Table C.4-1—Postulated CPC-Related Facility Radiological Accidents

Accident	Accident Description	Material at Risk	Source Term	Event Frequency
Natural Phenomena Events				
1. Beyond Evaluation Basis Earthquake With Fire	A seismic event is postulated causing failure of interior nonstructural walls. The collapsed walls cause a loss of confinement and a potential release of materials in multiple areas of the facility. Combustible materials in the area are ignited and the fire propagates to multiple areas and storage vaults containing the largest quantity of plutonium metal.	16,988 kg plutonium-239 equivalent: 99.65% metal 0.21% powder 0.14% solution	4.23 kg metal 0.0021 kg oxide 0.048 kg solution	1.0×10^{-6} to 1.0×10^{-5}/yr
Externally Initiated Events				
Addressed in Classified Appendix	Addressed in Classified Appendix	Addressed in Classified Appendix	Addressed in Classified Appendix	Addressed in Classified Appendix
Internal Process Events				
1. Fire in a Single Building	A fire is postulated to start within a glovebox, processing room or storage vault. The fire propagates to multiple areas involving the largest quantities of plutonium metal.	7,685 kg plutonium metal	1.92 kg plutonium	1.0×10^{-6} to 1.0×10^{-4}/yr
2. Explosion in a Feed Casting Furnace	A steam explosion/over-pressurization is postulated to occur in a feed casting furnace in the foundry. The steam explosion occurs due to a cooling water leak or an over-pressurization event. The explosion/over-pressurization impacts molten plutonium metal in seven furnaces. Negligible impacts from the shock/blast are postulated for the solid plutonium metal in the glovebox.	4.5 kg molten plutonium metal	2.25 kg molten plutonium metal	1.0×10^{-4} to 1.0×10^{-2}/yr
3. Nuclear Criticality	An inadvertent criticality is postulated based on several potential events involving handling errors. Accumulation of fissile material in excess of criticality safety limits, addition of a moderator causing a critical configuration, or a seismic event causing collapse of storage vault racks are potential scenarios.	See Table 3–1[a]	5×10^{17} fissions	1.0×10^{-2}/yr

Table C.4-1—Postulated CPC-Related Facility Radiological Accidents (continued)

Accident	Accident Description	Material at Risk	Source Term	Event Frequency
Internal Process Events *(continued)*				
4. Fire-induced Release in the CRT Storage Room	A fire is postulated to occur in the cargo restraint transporter storage room.	600 kg plutonium metal	0.15 kg plutonium	1.0×10^{-4} to 1.0×10^{-2}/yr
5. Radioactive Material Spill	A loss of confinement and spill of molten plutonium into the metal reduction glovebox is postulated. The spill occurs due to a failure or rupture of the feed casting furnace.	4.5 kg molten plutonium metal	0.045 kg plutonium	1.0×10^{-4} to 1.0×10^{-2}/yr

[a] Tetra Tech 2008.
Source: Tetra Tech 2008.

Table C.4-2—Postulated CPC-Related Facility Chemical Accidents

Chemical Release Events				
1. Nitric Acid Release From Bulk Storage	Nitric acid is inadvertently released from bulk storage due to natural phenomena, equipment failure, mechanical impact, or human error during storage, handling, or process operations.	*10,500 kg*	*10,500 kg*	1.0×10^{-5} to 1.0×10^{-4}/yr
2. Hydrofluoric Acid Release From Bulk Storage	Hydrofluoric acid is inadvertently released from bulk storage due to natural phenomena, equipment failure, mechanical impact, or human error during storage, handling, or process operations.	*550 kg*	*550 kg*	1.0×10^{-5} to 1.0×10^{-4}/yr
3. Formic Acid Release From Bulk Storage	Formic acid is inadvertently released from bulk storage due to natural phenomena, equipment failure, mechanical impact, or human error during storage, handling, or process operations.	*1,500 kg*	*1,500 kg*	1.0×10^{-5} to 1.0×10^{-4}/yr

Source: Tetra Tech 2008.

Explosion in a feed casting furnace. A steam explosion/over-pressurization is postulated to occur in a feed casting furnace in the foundry. The steam explosion occurs due to a cooling water leak or an over-pressurization event. The explosion/over-pressurization impacts molten plutonium metal in seven furnaces. The furnace is assumed to contain 4.5 kilogram (9.9 pounds) of plutonium in the form of molten metal. The airborne respirable release fraction was estimated to be ARF × RF = 0.5 for the 4.5 kilogram (9.9 pounds) of plutonium. Negligible impacts from the shock/blast are postulated for 9 kilogram (19.8 pound) of solid plutonium metal in the glovebox. The bounding scenario assumes a DR = 1.0 and an LPF = 1.0. The resulting source is 2.25 kilogram (5.0 pounds) of plutonium. The frequency of the accident is estimated to be in the range of from 1×10^{-4} to 1×10^{-2} per year. For the purpose of risk calculations, a conservative frequency of 1×10^{-2} was used (Tetra Tech 2008).

Nuclear criticality. An inadvertent criticality is postulated based on any one of several potential events involving handling errors. Accumulation of fissile material in excess of criticality safety limits, addition of a moderator causing a critical configuration, or a seismic event causing collapse of storage vault racks are potential scenarios. The estimated frequency of a criticality is 1×10^{-2} per year (Tetra Tech 2008).

Fire-induced release in the cargo restraint transporter storage room. A fire is postulated to start in cargo restraint transporter storage room. The fire is confined to the room. The MAR in the room is 600 kilogram (1,322.8 pounds) plutonium metal. The bounding scenario assumes a DR = 1.0 resulting in all of the MAR to be affected by the fire. No credit is taken for building confinement or filtration resulting in an assumed LPF = 1.0. The airborne respirable fraction is estimated to be ARF × RF = 2.5×10^{-4}. No credit is taken for the mitigating effects of fire suppression efforts and equipment, plutonium cladding, or shipping containers. The resulting source term is a ground-level thermal release of 0.15 kilogram (0.33 pound) of plutonium. The accident frequency is estimated to be in the range of from 1×10^{-4} to 1×10^{-2} per year. For the purpose of risk calculations, a conservative frequency of 1×10^{-2} per year is assumed (Tetra Tech 2008).

Radioactive material spill. A spill of radioactive material occurs in the metal reduction glovebox. A loss of confinement and spill of molten plutonium into the metal reduction glovebox is postulated. The spill occurs due to a failure or rupture of the feed casting furnace. The event does not impact any other material that may be in the glovebox. The spill is assumed to involve 4.5 kilogram (9.9 pounds) molten plutonium metal. An airborne release from disturbed metal surfaces is assumed the release mechanism. The airborne respirable release fraction is estimated to be ARF × RF = 1×10^{-2}. A DR = 1.0 was conservatively assumed. For a bounding scenario, no credit is taken for safety systems, building confinement, or ventilation/filtration corresponding to LPF = 1.0. The resulting source term is a ground level release of 0.045 kilogram (0.099 pounds) of plutonium. The accident frequency is estimated to be in the range of from 1×10^{-4} to 1×10^{-2} per year. For the purpose of risk calculations, a conservative frequency of 1×10^{-2} per year is assumed (Tetra Tech 2008).

Nitric acid release. An accidental release of nitric acid from bulk storage is postulated due to equipment failure, mechanical impact, or human error. The accident scenario postulates a major leak, such as a pipe rupture, and the released chemical forming a pool about one inch in depth in the area around the point of release. Nitric acid is corrosive and can cause severe burns to all parts of the body. Its vapors may burn the respiratory tract and may cause pulmonary edema, which could prove fatal. The nitric acid is assumed to be stored in bulk quantity in an outdoor facility at a modern pit facility (MPF). The maximum amount of nitric acid that could be released is 10,500 kilogram (23,149 lb). The nitric acid is released by evaporation to the environment and is transported as an airborne plume with potential impacts in excess of ERPG-2 and ERPG-3 concentration limits to onsite workers and the offsite public. The ERPG-2 and ERPG-3 concentration limits for the chemical are 6 and 78 parts per million (ppm), respectively. The estimated frequency of this accident is in the range of from 1.0×10^{-5} to 1.0×10^{-4} per year. For the purpose of risk calculations, a conservative frequency of 1.0×10^{-4} is assumed (Tetra Tech 2008).

Hydrofluoric acid release. An accidental release of hydrofluoric acid from bulk storage is postulated due to equipment failure, mechanical impact, or human error. Hydrofluoric acid is extremely toxic and may be fatal if inhaled or ingested. It is readily absorbed through the skin, and skin contact may be fatal. It acts as a systemic poison, causes severe burns, and is a possible mutagen. The hydrofluoric acid is assumed to be stored in bulk quantity in an outdoor facility at MPF. The maximum amount of hydrofluoric acid that could be released is 550 kilogram (1,212.5 pounds). The hydrofluoric acid is released by evaporation to the environment and is transported as an airborne plume with potential impacts in excess of ERPG-2 and ERPG-3 concentration limits to onsite workers and the offsite public. The ERPG-2 and ERPG-3 concentration limits for the chemical are 20 and 50 ppm, respectively. The estimated frequency of this accident is in the range of from 1.0×10^{-5} to 1.0×10^{-4} per year. For the purpose of risk calculations, a conservative frequency of 1.0×10^{-4} per year is assumed (Tetra Tech 2008).

Formic acid release. An accidental release of formic acid from bulk storage is postulated due to equipment failure, mechanical impact, or human error. The accident scenario postulates a major leak, such as a pipe rupture, and the released chemical forming a pool about one inch in depth in the area around the point of release. Formic acid is corrosive and will cause severe burns. It is harmful by inhalation, ingestion, and readily absorbed through skin. It is very destructive to mucous membranes and the upper respiratory tract, eyes, and skin. Inhalation may be fatal. The formic acid is assumed to be stored in bulk quantity in an outdoor facility at MPF. The maximum amount of formic acid that could be released is 1,500 kilogram (3,307 pounds). The formic acid is released by evaporation to the environment and is transported as an airborne plume with potential impacts in excess of ERPG-2- and ERPG-3-concentration limits to onsite workers and the offsite public. The ERPG-2- and ERPG-3-concentration limits for the chemical are 10 and 30 ppm, respectively. The estimated frequency of this accident is in the range of from 1.0×10^{-5} to 1.0×10^{-4} per year. For the purpose of risk calculations, a conservative frequency of 1.0×10^{-4} per year is assumed (Tetra Tech 2008).

Results. Tables C.4-3 through C.4-12 show the consequences and risks of the postulated set of accidents for a noninvolved worker and the public (MEI and the general population living within 50 miles of the site), for the site alternatives for the CPC. Chemical accidents are shown in Tables C.4-13 through C.4-18.

C.4.2 LANL Alternative

C.4.2.1 *Greenfield CPC and Upgrade Alternative*

Table C.4-3—CPC Radiological Accident Frequency and Consequences at LANL

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Frequency (per year)**	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Beyond Evaluation Basis Earthquake and Fire	1.0×10^{-5}	87.5	0.105	44,200	26.5	1,420	1.0
Fire in a Single Building	1.0×10^{-4}	62.4	0.0749	27,600	16.6	2,200	1.0
Explosion in a Feed Casting Furnace	1.0×10^{-2}	73.2	0.0878	32,400	19.4	2,580	1.0
Nuclear Criticality	1.0×10^{-2}	0.00014	8.40×10^{-8}	0.0372	2.23×10^{-5}	0.00278	1.67×10^{-6}
Fire-Induced Release in the CRT Storage Room	1.0×10^{-2}	4.88	0.00293	2,160	1.3	172	0.206
Radioactive Material Spill	1×10^{-2}	0.146	8.76×10^{-5}	64.8	0.0389	5.16	0.0031

Source: Tetra Tech 2008.
[a] CPC operations at TA55; at site boundary, approximately 0.7 miles from release.
[b] Based on a projected future population (year 2030) of approximately 552,115 persons residing within 50 miles of LANL TA55 location.
[c] At a distance of 1,000 meters.

Table C.4-4—Annual Cancer Risks for CPC at LANL

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Beyond Evaluation Basis Earthquake with Fire	1.05×10^{-6}	2.65×10^{-4}	1×10^{-5}
Fire in a Single Building	7.49×10^{-6}	1.66×10^{-3}	1×10^{-4}
Explosion in a Feed Casting Furnace	8.78×10^{-4}	0.19	1×10^{-2}
Nuclear Criticality	8.40×10^{-10}	2.23×10^{-7}	1.67×10^{8}
Fire-induced Release in the CRT Storage Room	2.93×10^{-5}	1.3×10^{-2}	2.06×10^{-3}
Radioactive Material Spill	8.76×10^{-7}	3.89×10^{-4}	3.1×10^{-5}

Source: Tetra Tech 2008.
[a] CPC operations at TA55; at site boundary, approximately 0.7 miles from release.
[b] Based on a projected future population (year 2030) of approximately 552,115 persons residing within 50 miles of LANL TA55 location.
[c] At a distance of 1,000 meters.

C.4.2.2 *50/80 Alternative*

Under the 50/80 Alternatives at Los Alamos, the Plutonium Facility, Building 4 (PF-4) at TA-55 would be upgraded to provide a capability to produce up to 80 pits/year to the stockpile. The changes to PF-4 to achieve this capability are assumed to be equivalent to the operations, processes, and technology and safety systems planned for a Greenfield CPC. As such, the potential hazards and accidents postulated for a Greenfield CPC would be applicable to the upgraded PF-4. However, for three of the accidents (Beyond Evaluation Basis Earthquake and Fire, Fire in a single building, and the Fire-induced release in the CRT Storage Room), the material-at-risk for the 50/80 Alternative would be approximately two-thirds as large as for the Greenfield CPC. The potential consequences and risks from accidents for the 50/80 Alternative are presented in Tables C.4-3a and C.4-4a.

Table C.4-3a—CPC Radiological Accident Frequency and Consequences at LANL for the 50/80 Alternative

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Frequency (per year)**	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Beyond Evaluation Basis Earthquake and Fire	1.0×10^{-5}	58.6	0.07	29,614	17.8	951	1.0
Fire in a Single Building	1.0×10^{-4}	41.8	0.05	18,492	11.1	1,474	1.0
Explosion in a Feed Casting furnace	1.0×10^{-2}	73.2	0.0878	32,400	19.4	2,580	1.0
Nuclear Criticality	1.0×10^{-2}	0.00014	$8.40x10^{-8}$	0.0372	$2.23x10^{-5}$	0.00278	$1.67x10^{-6}$
Fire-Induced Release in the CRT Storage Room	1.0×10^{-2}	3.3	0.002	1,447	0.9	115	0.13

Table C.4-3a—CPC Radiological Accident Frequency and Consequences at LANL for the 50/80 Alternative (continued)

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Frequency (per year)**	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Radioactive Material Spill	1×10^{-2}	0.146	$8.76x10^{-5}$	64.8	0.0389	5.16	0.003

[a] CPC operations at TA55; at site boundary, approximately 0.7 miles from release.
[b] Based on a projected future population (year 2030) of approximately 552,115 persons residing within 50 miles of LANL TA55 location.
[c] At a distance of 1,000 meters.
Source: Tetra Tech 2008

Table C.4-4a—Annual Cancer Risks for CPC at LANL for the 50/80 Alternative

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Beyond Evaluation Basis Earthquake With Fire	7.0×10^{-7}	1.78×10^{-4}	1×10^{-5}
Fire in a Single Building	5.0×10^{-6}	1.1×10^{-3}	1×10^{-4}
Explosion in a Feed Casting Furnace	8.78×10^{-4}	0.19	1×10^{-2}
Nuclear Criticality	8.40×10^{-10}	2.23×10^{-7}	1.67×10^{8}
Fire-induced Release in the CRT Storage Room	2.0×10^{-5}	9.0×10^{-3}	1.3×10^{-3}
Radioactive Material Spill	8.76×10^{-7}	3.89×10^{-4}	3.1×10^{-5}

Source: Tetra Tech 2008.
[a] CPC operations at TA55; at site boundary, approximately 0.7 miles from release.
[b] Based on a projected future population (year 2030) of approximately 552,115 persons residing within 50 miles of LANL TA55 location.
[c] At a distance of 1,000 meters.

C.4.3 Nevada Test Site Alternative

Table C.4-5—CPC Radiological Accident Frequency and Consequence–NTS

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	Frequency	Dose (rem)	Latent Cancer Fatalities	Dose (Person-rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
Beyond Evaluation Basis Earthquake and Fire	1.0×10^{-5}	1.99	0.00119	788	0.473	1,770	1.0
Fire in a Single Building	1.0×10^{-4}	0.918	0.000551	354	0.212	984	1.0
Explosion in a Feed Casting Furnace	1.0×10^{-2}	1.08	0.000648	414	0.248	1,150	1.0
Nuclear Criticality	1.0×10^{-2}	1.89×10^{-6}	1.13×10^{-9}	0.000309	1.85×10^{-7}	0.00124	7.44×10^{-7}
Fire-Induced Release in the CRT Storage Room	1.0×10^{-2}	0.0717	0.000043	27.6	0.0166	76.8	0.0922
Radioactive Material Spill	1×10^{-2}	0.00215	1.29×10^{-6}	0.829	0.000497	2.31	0.00139

Source: Tetra Tech 2008.
[a] At site boundary, 13.7 miles from release.
[b] Based on a projected future population (year 2030) 60,138 persons residing within 50 miles of NTS location.
[c] At 1000 meters from release.

Table C.4-6—Annual Cancer Risks for CPC–NTS

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Beyond Evaluation Basis Earthquake With Fire	1.19×10^{-8}	4.73×10^{-6}	1×10^{-5}
Fire in a Single Building	5.51×10^{-8}	2.12×10^{-5}	1×10^{-4}
Explosion in a Feed Casting Furnace	6.48×10^{-6}	2.48×10^{-3}	1×10^{-2}
Nuclear Criticality	1.13×10^{-11}	1.85×10^{-9}	7.44×10^{-9}
Fire-Induced Release in the CRT Storage Room	4.3×10^{-7}	1.66×10^{-4}	9.22×10^{-4}
Radioactive Material Spill	1.29×10^{-8}	4.97×10^{-6}	1.39×10^{-5}

Source: Tetra Tech 2008.
[a] At site boundary, 13.7 miles from release.
[b] Based on a projected future population (year 2030) 60,138 persons residing within 50 miles of NTS location.
[c] At 1000 meters from release.

C.4.4 Pantex Site Alternative

Table C.4-7—CPC Radiological Accident Frequency and Consequences—Pantex

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	Frequency	Dose (rem)	Latent Cancer Fatalities	Dose (Person-rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
Beyond Evaluation Basis Earthquake and Fire	1.0×10^{-5}	23.1	0.0277	9,840	5.9	1,550	1.0
Fire in a Single Building	1.0×10^{-4}	11.4	0.00684	4,610	2.77	988	1.0
Explosion in a Feed Casting Furnace	1.0×10^{-2}	13.3	0.00798	5,400	3.24	1,160	1.0
Nuclear Criticality	1.0×10^{-2}	3.17×10^{-5}	1.90×10^{-8}	0.00446	2.68×10^{-6}	0.00126	7.56×10^{-7}
Fire-Induced Release in the CRT Storage Room	1.0×10^{-2}	0.888	0.000533	360	0.216	77.2	0.0926
Radioactive Material Spill	1×10^{-2}	0.0266	0.000016	10.8	0.00648	2.32	0.00139

Source: Tetra Tech 2008.
[a] At site boundary, approximately 2.2 miles from release.
[b] Based on a projected future population (year 2030) approximately 386,706 persons residing within 50 miles of Pantex location.
[c] At 1000 meters from release.

Table C.4-8—Annual Cancer Risks for CPC—Pantex

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Beyond Evaluation Basis Earthquake With Fire	2.77×10^{-7}	5.9×10^{-5}	1×10^{-5}
Fire in a Single Building	6.84×10^{-7}	2.77×10^{-4}	1×10^{-4}
Explosion in a Feed Casting Furnace	7.98×10^{-5}	3.24×10^{-2}	1×10^{-2}
Nuclear Criticality	1.90×10^{-10}	2.68×10^{-8}	7.56×10^{-9}
Fire-Induced Release in the CRT Storage Room	5.33×10^{-6}	2.16×10^{-3}	9.26×10^{-4}
Radioactive Material Spill	1.6×10^{-7}	6.48×10^{-5}	1.39×10^{-5}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 2.2 miles from release.
[b] Based on a projected future population (year 2030) approximately 386,706 persons residing within 50 miles of Pantex location.
[c] At 1000 meters from release.

C.4.5 Savannah River Site Alternative

Table C.4-9—CPC Radiological Accident Frequency and Consequences—SRS

		Maximally Exposed Individuala		Offsite Populationb		Noninvolved Workerc	
Accident	**Frequency**	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Beyond Evaluation Basis Earthquake and Fire	1.0×10^{-5}	3.39	0.00203	17,500	10.5	1,580	1.0
Fire in a Single Building	1.0×10^{-4}	1.57	0.000942	7,890	4.73	1,070	1.0
Explosion in a Feed casting furnace	1.0×10^{-2}	1.83	0.0011	9,250	5.55	1,260	1.0
Nuclear Criticality	1.0×10^{-2}	$3.42x10^{-6}$	$2.05x10^{-9}$	0.00728	$4.37x10^{-6}$	0.00146	$8.76x10^{-7}$
Fire-Induced Release in the CRT Storage Room	1.0×10^{-2}	0.122	$7.32x10^{-5}$	617	0.37	83.7	0.1
Radioactive Material Spill	1×10^{-2}	0.00367	$2.20x10^{-6}$	18.5	0.0111	2.51	0.00151

Source: Tetra Tech 2008.
[a] At site boundary, approximately 6.7 miles from release.
[b] Based on a projected future population (year 2030) of 985,980 persons residing within 50 miles of SRS location.
[c] At a distance of 1,000 meters.

Table C.4-10—Annual Cancer Risks for CPC—SRS

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Non-involved Worker[c]
Beyond Evaluation Basis Earthquake With Fire	$2.03x10^{-8}$	$1.05x10^{-4}$	$1x10^{-5}$
Fire in a Single Building	$9.42x10^{-8}$	$4.73x10^{-4}$	$1x10^{-4}$
Explosion in a Feed Casting Furnace	$1.1x10^{-5}$	$5.55x10^{-2}$	$1x10^{-2}$
Nuclear Criticality	$2.05x10^{-11}$	$4.37x10^{-8}$	$8.76x10^{-9}$
Fire-Induced Release in the CRT Storage Room	$7.32x10^{-7}$	$0.37 x10^{-7}$	$1x10^{-3}$
Radioactive Material Spill	$2.20x10^{-8}$	$1.11x10^{-4}$	$1.51x10^{-5}$

Source: Tetra Tech 2008.
[a] At site boundary, approximately 6.7 miles from release.
[b] Based on a projected future population (year 2030) of 985,980 persons residing within 50 miles of SRS location.
[c] At a distance of 1,000 meters.

C.4.6 Y-12 Alternative

Table C.4-11—CPC Radiological Accident Frequency and Consequences—Y-12

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Frequency**	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Beyond Evaluation Basis Earthquake and Fire	1.0×10^{-5}	219	0.263	295,000	177	857	1.0
Fire in a Single Building	1.0×10^{-4}	173	0.208	152,000	91.2	4,760	1.0
Explosion in a Feed Casting Furnace	1.0×10^{-2}	203	0.244	178,000	107	5,580	1.0
Nuclear Criticality	1.0×10^{-2}	0.000301	1.81×10^{-7}	0.117	7.02×10^{-5}	0.00544	3.26×10^{-6}
Fire-Induced Release in the CRT Storage Room	1.0×10^{-2}	13.5	0.0081	11,900	7.14	372	0.446
Radioactive Material Spill	1×10^{-2}	0.406	0.000244	357	0.214	11.2	0.00672

Source: Tetra Tech 2008.
[a] At site boundary, approximately 1.3 miles from release.
[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.
[c] At 1000 meters from release.

Table C.4-12—Annual Cancer Risks for CPC–Y-12

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Beyond Evaluation Basis Earthquake With Fire	2.63×10^{-6}	1.77×10^{-3}	1×10^{-5}
Fire in a Single Building	2.08×10^{-5}	9.12×10^{-3}	1×10^{-4}
Explosion in a Feed Casting Furnace	2.44×10^{-3}	1.07	1×10^{-2}
Nuclear Criticality	1.81×10^{-9}	7.02×10^{-7}	3.26×10^{-8}
Fire-Induced Release in the CRT Storage Room	8.1×10^{-5}	7.14×10^{-2}	4.46×10^{-3}
Radioactive Material Spill	2.44×10^{-6}	2.14×10^{-3}	6.72×10^{-5}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 1.3 miles from release.
[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.
[c] At 1000 meters from release.

C.4.7 Chemical Accident Frequency and Consequences—CPC

The chemicals selected for evaluation are based on the aqueous feed preparation process, as noted in each table, and are considered the most hazardous of all the chemicals used in this process. Determination of a chemical's hazardous ranking takes into account quantities available for release, protective concentration limits (ERPG-2), and evaporation rate. The most hazardous chemical used in an alternative method, the pyrochemical processing method is also analyzed as noted in the tables.

This section presents the impacts of potential chemical accidents at each of the five CPC site alternatives. The tables show the name of the chemical and the quantity released during a severe accident. The impacts of chemical releases are measured in terms of ERPG-2 protective concentration limits given in ppm. The distances at which the limit is reached are also provided for the ERPG-2 limit. The concentration of the chemical at 1,000 meters (3,281 feet) from the accident is shown for comparison with the concentration limit for ERPG-2. The distance to the site boundary and the concentration at the site boundary are also shown for comparison with the ERPG-2 concentration limits and for determining if the limits are exceeded offsite.

Table C.4-13—Chemical Accident Frequency and Consequences at Los Alamos

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration[a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)[b]	At Site Boundary(ppm)	
Nitric acid	10,500	6	0.85	4.5	8.76	10^{-4}
Hydrofluoric acid	550	20	0.5	5.05	10.4	10^{-4}
Formic acid	1,500	10	0.215	0.54	1.06	10^{-4}

[a] At site boundary, approximately 0.7 miles from release.

Table C.4-14—Upgrade 80 Chemical Accident Frequency and Consequences

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration[a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	3,420	6	0.5	1.46	2.85	10^{-4}
Hydrofluoric acid	340	20	0.4	3.1	6.42	10^{-4}
Hydrochloric acid	384	20	2.1	118	264	10^{-4}

[a] At site boundary, approximately 0.7 miles from release.

Table C.4-15—Chemical Accident Frequency and Consequences at NTS

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration[a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	10,500	6	0.86	4.55	<0.1	10^{-4}
Hydrofluoric acid	550	20	0.5	5.05	<0.1	10^{-4}
Formic acid	1,500	10	0.215	0.54	<0.1	10^{-4}

[a] Site boundary is at a distance of 13.7.

Table C.4-16—Chemical Accident Frequency and Consequences at Pantex

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration[a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	10,500	6	0.85	4.49	0.48	10^{-4}
Hydrofluoric acid	550	20	0.5	5.1	0.55	10^{-4}
Formic acid	1,500	10	0.22	0.56	<0.1	10^{-4}

[a] Site boundary is at a distance of 2.2 miles.

Table C.4-17—Chemical Accident Frequency and Consequences at SRS

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	10,500	6	0.17	0.189	<0.01	10^{-4}
Hydrofluoric acid	550	20	0.12	0.21	<0.01	10^{-4}
Formic acid	1,500	10	0.1	0.02	0	10^{-4}

[a] Site boundary is at a distance of 6.7 miles.

Table C.4-18—CPC Chemical Accident Frequency and Consequences at Y-12

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary(ppm)	
Nitric acid	10,500	6	0.28	0.5	0.01	10^{-4}
Hydrofluoric acid	550	20	0.35	2.0	0.016	10^{-4}
Formic acid	1,500	10	0.08	0.07	0	10^{-4}

[a] At site boundary, approximately 1.3 miles from release.

C.5 RADIOLOGICAL ACCIDENT SCENARIOS—CUC

This section presents the estimated impacts of accidents that could occur at a CUC. The scenarios described here define the bounding envelope of accidents—that is, any other reasonably foreseeable accident at the CUC would be expected to have similar or smaller consequences. These accident analyses are conservative, with little or no credit taken for existing preventative and mitigating features in each building or operation analyzed or the safety procedures that are mandatory at NNSA sites.

C.5.1 Accident Scenarios

From the safety documents obtained through the process described in Section C.3.1, Table C.5-1 identifies the accident scenarios and source terms (release rates and frequencies) that were developed for the CUC (Tetra Tech 2008).

Table C.5-1—Potential CUC Accident Scenarios

Accident	Frequency	Source Term or Hazard	Notes/Assumptions
EU Metal Fabrication Complex			
Local fire	$10^{-2} – 10^{-4}$	N/A, No radiological consequences	
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	1.0×10^{18} fissions
Major fire	$10^{-4} – 10^{-6}$	EU = 17.9 kg (sum of metal and chips) DU = 452 kg (sum of metal and chips)	Release height = ground level Release duration = 1 hr
Aircraft Crash—Initiator for major fire	$1.5\times10^{-5} – 2.2\times10^{-5}$	See major fire	
Tanker Truck Accident—Initiator for major fire	$10^{-4} – 10^{-6}$	See major fire	
Earthquake	$10^{-2} – 10^{-4}$	Same as criticality	
High Winds	$10^{-2} – 10^{-4}$	Same as earthquake	
Rain/Snow	$10^{-2} – 10^{-4}$	Same as earthquake	
Assembly			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	1.0×10^{18} fissions
Explosion	$10^{-4} – 10^{-6}$	2 kg EU (sum of metal and chips) 0.04 kg DU (sum of metal and chips)	Release height = 7.6 m Release duration =1 hr
Fire	$10^{-4} – 10^{-6}$	Same as explosion	Release height = 7.6 m Release duration = 2 hr
Earthquake	$10^{-2} – 10^{-4}$	Bounded by fire	
Wind	$10^{-1} – 10^{-2}$	None	
Flood	$10^{-2} – 10^{-4}$	None	
Aircraft crash	$\sim 2\times10^{-5}$	Bounded by fire	
Manufacturing QE			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	1.0×10^{18} fissions
Local fires	$10^{-2} – 10^{-4}$	No radiological releases	
Large Building Fire	$10^{-4} – 10^{-6}$	2.6 kg EU 54 kg DU 172 kg Th	Release height =<10 m Release duration = 1 hr
Aircraft Crash—Initiator for large building fire	$4.5\times10^{-5} – 5.0\times10^{-5}$	See large building fire	
Tanker Truck explosion—Initiator for large building fire	$10^{-4} – 10^{-6}$	See large building fire	
Earthquake	$10^{-2} – 10^{-4}$	Bounded by criticality	
Wind	$10^{-2} – 10^{-4}$	Bounded by criticality	
Rain/Snow	$10^{-2} – 10^{-4}$	Bounded by criticality	

Table C.5-1—Potential CUC Accident Scenarios (continued)

Accident	Frequency	Source Term or Hazard	Notes/Assumptions
EU Warehouse			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	$1.0{\times}10^{18}$ fissions
Fire	$10^{-4} – 10^{-6}$	EU = 22.6 kg DU = 20.1 kg U-233 = 0.0066 kg Th = 0.13 kg (represents sum of metals, oxides, and combustibles) Pu = $1.0{\times}10^{-6}$ kg Np-237 = $1.6{\times}10^{-5}$ kg	Release height = 4 m Release duration = 1 hr
Aircraft crash—Initiator of fire	$1.2{\times}10^{-5}$	Same as fire	
Earthquake-induced loss of confinement	$10^{-2} – 10^{-4}$	EU = 1.3 kg DU = 0.06 kg Th = 0.03 kg (the above all represent the sum of metals, oxides, and combustibles)	Release height = ground level Release duration = 15 min
Wind	$10^{-2} – 10^{-4}$	Bounded by criticality, fire	
Flood	$10^{-2} – 10^{-4}$	Bounded by criticality	
Lightning	$10^{-4} – 10^{-6}$	Bounded by fire	
HEUMF			
Design-basis fires[1]	$10^{-2} – 10^{-4}$	EU = 2.58 kg DU = 0.55 kg	Release height = 11.3 m Release duration = 1 hr
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	$1.0{\times}10^{18}$ fissions
Earthquake	$10^{-2} – 10^{-4}$	None	
Wind	$10^{-2} – 10^{-4}$	None	
Rain/Snow	$10^{-2} – 10^{-4}$	None	
Flood	$10^{-2} – 10^{-4}$	Bounded by criticality	
EU Operations			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	$1.0{\times}10^{18}$ fissions
Uranium Solution Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	$3.25{\times}10^{18}$ fissions
Local fires	$10^{-2} – 10^{-4}$	8 kg EU (includes aqueous and organic solutions	Release height = ground level Release duration = 15 min
Large fire	$10^{-4} – 10^{-6}$	14.8 kg EU (includes metals, oxides, aqueous and organic solutions)	Release height = “roof level” Release duration = 1 hr
Explosions	$10^{-2} – 10^{-4}$	None—localized effects	
Aircraft crash	$10^{-4} – 10^{-6}$	37.8 kg EU (includes metals, chips, oxides, and aqueous and organic solutions)	Release height = “roof level” Release duration = 15 min

[1] The source term for a design-basis fire at the HEUMF has been identified as the bounding (largest possible) source term, and reasonably bounds the source term that might result from any aircraft crash.

Table C.5-1—Potential CUC Accident Scenarios (continued)

Accident	Frequency	Source Term or Hazard	Notes/Assumptions
EU Operations *(continued)*			
Earthquake-induced fire	$10^{-2} – 10^{-4}$	Same as large fire	
Wind	$10^{-2} – 10^{-4}$	Bounded by earthquake	
Rain/Snow	$10^{-2} – 10^{-4}$	Bounded by earthquake	
Lightning	$10^{-2} – 10^{-4}$	Same as local fire	
Analytical Laboratory			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	1.0×10^{18} fissions
Large fire	$10^{-2} – 10^{-4}$	0.06 kg EA (includes solutions, metals, oxides, etc.)	
Aircraft crash	1.4×10^{-5}	Same as large fire	
Machine Shop Special Materials			
Large fire	$10^{-4} – 10^{-6}$	96.6 kg DU (includes metals, fines, and oxides)	Release height = ground level Release duration = 1 hr
Inadvertent water leak into furnace	$10^{-2} – 10^{-4}$	32 kg DU	Release height = ground level Release duration = "short" (assume 15 min)
Machine Shop DU/Binary			
Large fire	$10^{-4} – 10^{-6}$	31.3 kg DU (includes bulk metal, chips, and fines)	Release height = "elevated" Release duration = 1 hr
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Tables C.5-2 through C.5-4	1.0×10^{18} fissions
Earthquake	$10^{-2} – 10^{-4}$	Bounded by large fire	
High wind/tornado	$10^{-2} – 10^{-4}$	Bounded by large fire	
Rain/Snow	$10^{-2} – 10^{-4}$	Bounded by large fire	

Source: Tetra Tech 2008.

Table C.5-2—Source Term (Ci) Released to the Environment Following a Uranium Metal Criticality (1.0×10^{18} fissions)

Radionuclide	Half Life	Curies released
Kr-83m	1.8 hr	8.00E+00
Kr-85m	4.5 yr	7.50E+00
Kr-84	1.7 yr	8.00E-05
Kr-87	76.3 min	4.95E+01
Kr-88	2.8 hr	3.25E+01
Kr-89	3.2 min	2.10E+03
Xe-131m	11.9 day	4.10E-03
Xe-133m	2.0 day	9.00E-02
Xe-133	5.2 day	1.35E+00
Xe-135m	15.6 min	1.10E+02
Xe-135	9.1 hr	1.80E+01
Xe-137	3.8 min	2.45E+03
Xe-138	14.2 min	6.50E+02
I-131	8.1 day	4.35E-02
I-132	2.3 hr	5.50E+00
I-133	0.8 hr	8.00E-01
I-134	52.6 min	2.25E+01
I-135	6.6 hr	2.35E+00

Source: Tetra Tech 2008.

Table C.5-3—Source Term (Ci)–Uranium Solution Criticality (3.28×10^{18} fissions)

Radionuclide	Half Life	Curies released
Kr-83m	1.8 hr	5.25E+01
Kr-85m	4.5 yr	4.92E+01
Kr-84	1.7 yr	5.25E-04
Kr-87	76.3 min	3.25E+02
Kr-88	2.8 hr	2.13E+02
Kr-89	3.2 min	1.38E+04
Xe-131m	11.9 day	2.69E-02
Xe-133m	2.0 day	5.90E-01
Xe-133	5.2 day	8.86E+00
Xe-135m	15.6 min	7.22E+02
Xe-135	9.1 hr	1.18E+02
Xe-137	3.8 min	1.61E+04
Xe-138	14.2 min	4.26E+03
I-131	8.1 day	7.13E-01
I-132	2.3 hr	9.02E+01
I-133	0.8 hr	1.31E+01
I-134	52.6 min	3.69E+02
I-135	6.6 hr	3.85E+01

Source: Tetra Tech 2008.

Table C.5-4—Estimated Direct Radiation Dose From an Unshielded Criticality Accident

Downwind Distance (m)	Direct Radiation Dose (rem)	
	Uranium metal criticality	Uranium solution criticality
100	5.7	18.6
200	0.88	2.9
300	0.25	0.81
350	0.14	0.47
400	0.088	0.29
450	0.056	0.18
500	0.036	0.12
550	0.024	0.079
600	0.016	0.053
650	0.011	0.036
700	0.0077	0.025
750	0.0054	0.018
800	0.0039	0.013
850	0.0028	0.0091
900	0.0020	0.0066
950	0.0015	0.0048
1000	0.0011	0.0036

Source: Tetra Tech 2008.

C.5.2 Estimated Health Effects

Table C.5-5 identifies the accidents that are analyzed in this SPEIS for the CUC. Tables C.5-6 through C.6-17 show the consequences and risks of the postulated set of accidents for a noninvolved worker and the public (MEI and the general population living within 50 miles of the site), for the site alternatives for the CUC.

Table C.5-5—Uranium Operations Accidents

Operation	Accident	Frequency	Source Term	Notes/Assumptions
EU Metal Fabrication	Major fire	$10^{-4} – 10^{-6}$	EU = 17.9 kg (sum of metal and chips) DU = 452 kg (sum of metal and chips)	Release height = ground level Release duration = 1 hour
Assembly	Explosion	$10^{-4} – 10^{-6}$	2 kg EU (sum of metal and chips) 0.04 kg DU (sum of metal and chips)	Release height = 7.6 m Release duration =1 hour
EU Warehouse	Fire	$10^{-4} – 10^{-6}$	EU = 22.6 kg DU = 20.1 kg U-233 = 0.0066 kg Th = 0.13 kg (the above all represent the sum of metals, oxides, and combustibles) Pu = $1.0×10^{-6}$ kg Np-237 = $1.6×10^{-5}$ kg	Release height = 4 m Release duration = 1 hour
HEUMF	Design-basis fires	$10^{-2} – 10^{-4}$	EU = 2.58 kg DU = 0.55 kg	Release height = 11.3 m Release duration = 1 hour
EU Operations	Aircraft crash	$10^{-4} – 10^{-6}$	37.8 kg EU (includes metals, chips, oxides, and aqueous and organic solutions)	Release height = “roof level” Release duration = 15 min

Source: Tetra Tech 2008.

Table C.5-6—CUC Radiological Accident Frequency and Consequences at Los Alamos, TA-55 [a]

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	Frequency (per year)	Dose (rem)	Latent Cancer Fatalities	Dose (Person-rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
Major fire	$10^{-4} – 10^{-6}$	0.213	1.28×10^{-4}	94.5	5.67×10^{-2}	7.53	4.52×10^{-3}
Explosion	$10^{-4} – 10^{-6}$	0.0209	1.25×10^{-5}	9.3	5.58×10^{-3}	0.612	3.67×10^{-4}
Fire in EU Warehouse	$10^{-4} – 10^{-6}$	0.249	1.49×10^{-4}	110	6.6×10^{-2}	8.33	5.0×10^{-3}
Design-basis fires for HEU Storage	$10^{-2} – 10^{-4}$	0.0267	1.6×10^{-5}	12	7.2×10^{-3}	0.637	3.82×10^{-4}
Aircraft crash	$10^{-4} – 10^{-6}$	0.132	7.92×10^{-5}	75.5	4.53×10^{-2}	0.8	4.8×10^{-4}

Source: Tetra Tech 2008.
[a] CPC operations at TA55; at site boundary, approximately 0.7 miles from release.
[b] Based on a projected future population (year 2030) of approximately 552,115 persons residing within 50 miles of LANL TA55 location.
[c] At a distance of 1,000 meters.

Table C.5-7—Annual Cancer Risks for CUC at Los Alamos, TA-55

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Major fire	1.28×10^{-8}	5.67×10^{-6}	4.52×10^{-7}
Explosion	1.25×10^{-9}	5.58×10^{-7}	3.67×10^{-8}
Fire in EU Warehouse	1.49×10^{-8}	6.6×10^{-6}	5.0×10^{-7}
Design-basis fires for HEU Storage	1.6×10^{-7}	7.2×10^{-5}	3.82×10^{-6}
Aircraft crash	7.92×10^{-9}	4.53×10^{-6}	4.8×10^{-8}

Source: Tetra Tech 2008.
[a] CPC operations at TA55; at site boundary, approximately 0.7 miles from release.
[b] Based on a projected future population (year 2030) of approximately 552,115 persons residing within 50 miles of LANL TA55 location.
[c] At a distance of 1,000 meters.

Table C.5-8—Potential Accident Consequences—CUC at Los Alamos, TA-16[a]

	Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	Dose (rem)	Latent Cancer Fatalities	Dose (Person-rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
EU Metal Fabrication	0.798	4.79×10^{-4}	60.3	3.62×10^{-2}	7.53	4.52×10^{-7}
Assembly	0.0768	4.61×10^{-5}	5.95	3.57×10^{-3}	0.612	3.67×10^{-8}
EU Warehouse	0.926	5.56×10^{-4}	70.6	4.24×10^{-2}	8.33	5.0×10^{-7}
HEUMF	0.0961	5.77×10^{-5}	7.7	4.62×10^{-3}	0.637	3.82×10^{-6}
EU Operations	0.158	9.48×10^{-5}	68.2	4.09×10^{-2}	0.8	4.8×10^{-8}

Source: Tetra Tech 2008.
[a] LANL Option 2 Uranium Operations would be at TA16. At site boundary, approximately 0.5 miles from release.
[b] Based on a projected future population (year 2030) of approximately 712,238 persons residing within 50 miles of TA-16 location.
[c] At a distance of 1,000 meters.

Table C.5-9—Annual Cancer Risks for CUC at Los Alamos, TA-16

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Major fire	4.79×10^{-8}	3.62×10^{-6}	0.00452
Explosion	4.61×10^{-9}	3.57×10^{-7}	0.000367
Fire in EU Warehouse	5.56×10^{-8}	4.24×10^{-6}	0.005
Design-basis fires for HEU Storage	5.77×10^{-7}	4.62×10^{-5}	0.000382
Aircraft crash	9.48×10^{-9}	4.09×10^{-6}	0.00048

Source: Tetra Tech 2008.
[a] LANL Option 2 Uranium Operations would be at TA16. At site boundary, approximately 0.5 miles from release.
[b] Based on a projected future population (year 2030) of approximately 712,238 persons residing within 50 miles of TA-16 location.
[c] At a distance of 1,000 meters.

Table C.5-10—CUC Radiological Accident Frequency, Consequences, and Risks at NTS

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	Frequency (per year)	Dose (rem)	Latent Cancer Fatalities	Dose (Person-rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
Major fire	$10^{-4} – 10^{-6}$	0.00314	1.88×10^{-6}	1.21	0.000726	3.36	0.00202
Explosion	$10^{-4} – 10^{-6}$	0.000309	1.85×10^{-7}	0.119	0.0000714	0.252	0.000151
Fire in EU Warehouse	$10^{-4} – 10^{-6}$	0.00366	2.20×10^{-6}	1.41	0.000846	3.63	0.00218
Design-basis fires for HEU Storage	$10^{-2} – 10^{-4}$	0.000398	2.39×10^{-7}	0.155	0.000093	0.243	0.000146
Aircraft crash[d]	$10^{-4} – 10^{-6}$	0.0071	4.26×10^{-6}	2.28	0.00137	2.13	0.00128

Source: Tetra Tech 2008.
[a] At site boundary, 13.7 miles from release.
[b] Based on a projected future population (year 2030) 60,138 persons residing within 50 miles of NTS location.
[c] At 1000 meters from release.
[e] NTS has controlled airspace over approximately 8000 square miles. Aircraft accidents are extremely unlikely and, therefore, are usually excluded from further analysis at the NTS. This accident is included as a comparison to other CUC sites.

Table C.5-11—Annual Cancer Risks for CUC at NTS

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Major fire	1.88×10^{-10}	7.26×10^{-8}	2.02×10^{-7}
Explosion	1.85×10^{-11}	7.14×10^{-9}	1.51×10^{-8}
Fire in EU Warehouse	2.20×10^{-10}	8.46×10^{-8}	2.18×10^{-7}
Design-basis fires for HEU Storage	2.39×10^{-9}	9.3×10^{-7}	1.46×10^{-6}
Aircraft crash	4.26×10^{-10}	1.37×10^{-7}	1.28×10^{-7}

Source: Tetra Tech 2008.
[a] At site boundary, 13.7 miles from release.
[b] Based on a projected future population (year 2030) 60,138 persons residing within 50 miles of NTS location.
[c] At 1000 meters from release.

Table C.5-12—CUC Radiological Accident Frequency and Consequences at Pantex

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Frequency (per year)**	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Major fire	$10^{-4} – 10^{-6}$	0.0388	0.0000233	15.8	0.00948	3.38	0.00203
Explosion	$10^{-4} – 10^{-6}$	0.00383	$2.30x10^{-6}$	1.56	0.000936	0.283	0.00017
Fire in EU Warehouse	$10^{-4} – 10^{-6}$	0.0454	0.0000272	18.4	0.011	3.77	0.00226
Design-basis fires for HEU Storage	$10^{-2} – 10^{-4}$	0.00494	$2.96x10^{-6}$	2.01	0.00121	0.303	0.000182
Aircraft crash	$10^{-4} – 10^{-6}$	0.0719	0.0000431	26.4	0.0158	2.68	0.00161

[a] At site boundary, approximately 2.2 miles from release.
[b] Based on a projected future population (year 2030) approximately 386,706 persons residing within 50 miles of Pantex location.
[c] At 1000 meters from release.
Source: Tetra Tech 2008.

Table C.5-13—Annual Cancer Risks for CUC at Pantex

Accident	Maximally Exposed Offsite Individual[a]	Offsite Population[a,b]	Noninvolved Worker[a,c]
Major fire	2.33×10^{-9}	9.48×10^{-7}	2.03×10^{-7}
Explosion	$2.30x10^{-10}$	9.36×10^{-8}	1.7×10^{-8}
Fire in EU Warehouse	2.72×10^{-9}	1.1×10^{-6}	2.26×10^{-7}
Design-basis fires for HEU Storage	$2.96x10^{-8}$	1.21×10^{-5}	1.82×10^{-6}
Aircraft crash	4.31×10^{-9}	1.58×10^{-6}	1.61×10^{-7}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 2.2 miles from release.
[b] Based on a projected future population (year 2030) approximately 386,706 persons residing within 50 miles of Pantex location.
[c] At 1000 meters from release.

Table C.5-14—Potential Accident Consequences—CUC at SRS

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Frequency (per year)**	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Major fire	$10^{-4} – 10^{-6}$	0.00535	3.21×10^{-6}	27	0.0162	3.66	0.0022
Explosion	$10^{-4} – 10^{-6}$	0.000528	3.17×10^{-7}	2.67	0.0016	0.313	0.000188
Fire in EU Warehouse	$10^{-4} – 10^{-6}$	0.00625	3.75×10^{-6}	31.5	0.0189	4.11	0.00247
Design-basis fires for HEU Storage	$10^{-2} – 10^{-4}$	0.000682	4.09×10^{-7}	3.45	0.00207	0.344	0.000206
Aircraft crash	$10^{-4} – 10^{-6}$	0.011	6.60×10^{-6}	47.3	0.0284	1.28	0.000768

Source: Tetra Tech 2008.
[a] At site boundary, approximately 6.7 miles from release.
[b] Based on a projected future population (year 2030) of 985,980 persons residing within 50 miles of SRS location.
[c] At a distance of 1,000 meters.

Table C.5-15—Annual Cancer Risks for CUC at SRS

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Major fire	3.21×10^{-10}	1.62×10^{-6}	2.2×10^{-7}
Explosion	3.17×10^{-11}	1.6×10^{-7}	1.88×10^{-8}
Fire in EU Warehouse	3.75×10^{-10}	1.89×10^{-6}	2.47×10^{-6}
Design-basis fires for HEU Storage	4.09×10^{-9}	2.07×10^{-5}	2.06×10^{-6}
Aircraft crash	6.60×10^{-10}	2.84×10^{-6}	7.68×10^{-8}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 6.7 miles from release.
[b] Based on a projected future population (year 2030) of 985,980 persons residing within 50 miles of SRS location.
[c] At a distance of 1,000 meters.

Table C.5-16—UPF or Upgraded Facilities, Radiological Accident Frequency and Consequences at Y-12

		Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	Frequency (per year)	Dose (rem)	Latent Cancer Fatalities	Dose (Person-rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
Major fire	$10^{-4} – 10^{-6}$	0.592	0.000355	520	0.312	16.3	0.00978
Explosion	$10^{-4} – 10^{-6}$	0.0577	0.0000346	51.2	0.0307	1.18	0.000708
Fire in UPF Warehouse	$10^{-4} – 10^{-6}$	0.689	0.000413	608	0.365	17.4	0.0104
Design-basis fires for HEU Storage	$10^{-2} – 10^{-4}$	0.0734	0.000044	66.1	0.0397	1.08	0.000648
Aircraft crash	$10^{-4} – 10^{-6}$	0.259	0.000155	665	0.399	0.388	0.000233

[a] At site boundary, approximately 1.3 miles from release.
[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.
[c] At 1000 meters from release.
Source: Tetra Tech 2008.

Table C.5-17—Annual Cancer Risks for CUC at Y-12

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Major fire	3.55×10^{-8}	3.12×10^{-5}	9.78×10^{-7}
Explosion	3.46×10^{-9}	3.07×10^{-6}	7.08×10^{-8}
Fire in UPF Warehouse	4.13×10^{-8}	3.65×10^{-5}	1.04×10^{-6}
Design-basis fires for HEU Storage	4.4×10^{-7}	3.97×10^{-4}	6.48×10^{-6}
Aircraft crash	1.55×10^{-8}	3.99×10^{-5}	2.33×10^{-8}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 1.3 miles from release.
[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.
[c] At 1000 meters from release.

C.5.3 Involved Worker Impacts

Workers in the facility where the accident occurs would be particularly vulnerable to the effects of the accident because of their location. For all of the accidents, there is a potential for injury or death to involved workers in the vicinity of the accident. However, prediction of latent potential health effects becomes increasingly difficult to quantify for facility workers as the distance between the accident location and the worker decreases. This is because the individual worker exposure cannot be precisely defined with respect to the presence of shielding and other protective features. The worker also may be injured or killed by physical effects of the accident itself.

C.5.4 CUC Chemical Accident Frequency and Consequences

The chemicals selected for evaluation are based on the aqueous feed preparation process, as noted in each table, and are considered the most hazardous of all the chemicals used in this process. Determination of a chemical's hazardous ranking takes into account quantities available for release, protective concentration limits (ERPG-2) and evaporation rate. This section presents the impacts of potential chemical accidents at each of the five CUC site alternatives. The tables show the name of the chemical and the quantity released during a severe accident. The impacts of chemical releases are measured in terms of ERPG-2 protective concentration limits given in parts per million. The distances at which the limit is reached are also provided for the ERPG-2 limit. The concentration of the chemical at 1,000 meters (3,281 feet) from the accident is shown for comparison with the concentration limit for ERPG-2. The distance to the site boundary and the concentration at the site boundary are also shown for comparison with the ERPG-2 concentration limits and for determining if the limits are exceeded offsite. Conservative modeling of chemical release over the period of one hour was based on a spill and subsequent pool with evaporation resulting calculated down-wind concentrations (Tetra Tech 2008).

Table C.5-18—Chemical Accident Frequency and Consequences at Los Alamos

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration[a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)[b]	
Nitric acid	10,500	6	0.85	4.5	8.76	10^{-4}

[a] Site boundary is at a distance of 1.2 miles.

Table C.5-19—Chemical Accident Frequency and Consequences at NTS

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration[a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	10,500	6	0.86	4.55	<0.1	10^{-4}

[a] Site boundary is at a distance of 13.7 miles.

Table C.5-20—Chemical Accident Frequency and Consequences at Pantex

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration[a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	10,500	6	0.85	4.49	0.48	10^{-4}

[a] Site boundary is at a distance of 2.2 miles.

Table C.5-21—Chemical Accident Frequency and Consequences at SRS

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	10,500	6	0.17	0.189	<0.01	10^{-4}

[a] Site boundary is at a distance of 6.7 miles.

Table C.5-22—Chemical Accident Frequency and Consequences at Y-12

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Nitric acid	10,500	6	0.28	0.5	0.01	10^{-4}

[a] Site boundary is at a distance of approximately 1.3 miles.

C.6 ACCIDENT SCENARIOS—A/D/HE CENTER

This section presents the estimated impacts of accidents that could occur at an A/D/HE Center. The scenarios described here define the bounding envelope of accidents—that is, any other reasonably foreseeable accident at the A/D/HE Center would be expected to have similar or smaller consequences. These accident analyses are conservative, with little or no credit taken for existing preventative and mitigating features in each building or operation analyzed or the safety procedures that are mandatory at NNSA sites.

C.6.1 Radiological Accident Scenarios

Facilities and operations at Pantex were analyzed to identify all hazards and potential accidents associated with the facilities and process systems, components, equipment, or structures and to establish design and operational means to mitigate these hazards to prevent potential accidents. The results of these analyses are contained in SARs and other safety basis documentation (see Section C.3.1).

For each facility and operation at Pantex, DOE has developed a safety analysis report. In addition, other facility-specific safety analyses have been performed and documented (e.g., process hazards reviews, hazards analysis documents, and justifications for continued operations). These documents were also utilized for the identification of potential accidents at Pantex. The next step of the screening process involved the identification of representative accidents that contribute to the risk to public and worker health from A/D/HE Center operations that would be similar to the operations currently performed at Pantex. Ideally, a complete evaluation of A/D/HE Center risks would include all potential accident scenarios. However, this type of an approach is impractical. Therefore, the purpose of this step in the screening process was to identify a subset of accident scenarios that contribute a large fraction of the total risk from A/D/HE Center operations. This step of the screening process involved the grouping of potential accidents based on both the magnitude of the frequency of occurrence and the magnitude of the expected consequence. Once the accidents were grouped, the accidents corresponding to the highest risk in each group were chosen for further analysis. For the accidents described below, which were identified as risk significant, consequence assessments were performed for the A/D/HE Center at the five site alternatives. Table C.6-1 presents the source terms for these accidents.

Scenario 1. Explosive-driven plutonium and tritium dispersal from an internal event. Nuclear weapons may be made with either conventional or insensitive HE, depending upon weapon design. Scenario 1 represents the accidental detonation of conventional HE in the presence of plutonium due to an internally initiated event. HE is present with radioactive materials in facilities where nuclear explosives work occurs. Initiators for this scenario include accidental actuation of an electro-explosive device during disassembly and handling accidents. Insensitive HE is a negligible risk contributor because it is not susceptible to ignition under the conditions existing during assembly or disassembly (A/D) operations. Insensitive HE is, thus, not a credible explosive source for this scenario.

Scenario 1 is comprised of three individual cases in which an accidental HE detonation is postulated to be initiated by an internal event. These cases differ in where the accidental detonation occurs; i.e., in a nuclear weapons A/D cell, a bay, or a special purpose building. An HE detonation during A/D would lead to the dispersal of radioactive material. Weapons are designed so that, in the event of an accidental detonation, there will be no significant nuclear reactions. Positive measures are engineered into nuclear explosives to preclude a nuclear yield from an accidental HE detonation.

The frequency of Scenario 1 is estimated to be 1.1 x 10^{-5} per year. It is, thus, *extremely unlikely* (frequency of occurrence is less than 10^{-4} per year but greater or equal to 10^{-6} per year). The derivation of this frequency involves summing of probabilities of different initiating events in different facilities. Explosive-driven plutonium dispersal from an internal event can result from operations conducted in bays, cells, or special purpose facilities. The probability per operation that an operational error could cause an explosive-driven plutonium and tritium release was estimated for each facility using data from available safety analyses (Tetra Tech 2008).

Scenario 2. Tritium reservoir failure from an internal event. This scenario represents the release of tritium due to a reservoir failure during normal operations. Initiators for this scenario include an inadvertent squib valve actuation during weapon operations.

This type of event has occurred at Pantex, and the frequency of this event is strongly dependent on the number of weapon operations being performed. For the 2,000 weapons activity level, this scenario is *anticipated* (frequency greater than or equal to 10^{-2} per year). For the 500 weapons activity level, this event is *unlikely* (frequency of occurrence is less than 10^{-2} per year but greater than or equal to 10^{-4} per year). This scenario is dominated by handling accidents during weapon operations (Tetra Tech 2008).

Scenario 3. Pit breach from an internal event. This scenario represents a pit breach, with resultant plutonium release, during normal operations. Initiators that contribute to this scenario include a pit drop due to a handling accident and a pit breach due to a forklift accident (Pantex 1996a, DOE 1994w). This scenario is dominated by handling accidents in bays and special purpose facilities. The overall likelihood of this scenario occurring is *unlikely* (frequency of occurrence is less than 10^{-2} per year but greater than or equal to 10^{-4} per year) (Tetra Tech 2008).

Scenario 4. Multiple tritium reservoir failure from an external event or natural phenomena. This scenario represents the release of tritium from reservoir failures caused by a fire in the tritium storage vault. The fire could be initiated by a seismic event or aircraft crash. The dominant event in this scenario is a seismic event initiated fire in the warehouse surrounding the tritium storage vault. For a release to occur, the protective vault fire door would have to be open and the fire protection system disabled by the seismic initiator. The overall likelihood of this scenario occurring is *not reasonably foreseeable* (frequency of occurrence is less than 10^{-6} per year) (Tetra Tech 2008).

Scenario 5. Fire-driven dispersal involving stored pits from an external event or natural phenomena. This scenario represents a pit breach, resulting in a plutonium release, initiated by a seismic event or aircraft accident. The overall likelihood of this scenario occurring is *extremely unlikely* (frequency of occurrence is less than 10^{-4} per year but greater or equal to 10^{-6} per year) (Tetra Tech 2008).

Scenario 6. Plutonium and tritium dispersal from an external event or natural phenomena. This scenario represents a tritium or plutonium release, without an explosion, caused by a seismic event or aircraft crash. Initiators include an aircraft impact-initiated fire in a nuclear explosive facility and a seismic collapse of a special purpose facility (Pantex 1993a). This scenario is dominated by seismic events resulting in structural failure of special purpose buildings containing nuclear explosives. Many stockpile support activities (e.g., testing and maintenance) are performed in older facilities without the structural strength of the storage magazines. Thus, these facilities are more vulnerable to external events and natural phenomena. The overall likelihood of this scenario occurring is *unlikely* (frequency of occurrence is less than 10^{-2} per year but greater than or equal to 10^{-4} per year) (Tetra Tech 2008).

Table C.6-1—Representative A/D/HE Accident Source Terms

Scenario	Pu Release (Ci)	Tritium Release (Ci)
Scenario 1	400	3.0×10^{5}
Scenario 2	0	2.0×10^{5}
Scenario 3	1.8×10^{-5}	0
Scenario 4	0	4.0×10^{7}
Scenario 5	50	0
Scenario 6	1.2×10^{-2}	3.0×10^{5}

Source: Tetra Tech 2008.

Table C.6-2—Potential Consequences of A/D/HE Accidents at LANL

	Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Scenario 1	73.8	0.0886	5,580	3.35	696	0.835
Scenario 2	0.0529	3.17×10^{-5}	4	2.4×10^{-3}	0.499	2.99×10^{-4}
Scenario 3	4.42×10^{-6}	2.65×10^{-9}	3.34×10^{-4}	2.00×10^{-7}	4.17×10^{-5}	2.50×10^{-8}
Scenario 4	1.31	7.86×10^{-4}	545	0.327	7.94	4.76×10^{-3}
Scenario 5	1.37	8.22×10^{-4}	570	0.342	8.3	4.98×10^{-3}
Scenario 6	0.0102	6.12×10^{-6}	4.23	2.5×10^{-3}	0.0615	3.69×10^{-5}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 0.5 miles from release.
[b] Based on a projected future population (year 2030) of approximately 712,238 persons residing within 50 miles of TA-16 location.
[c] At a distance of 1,000 meters.

Table C.6-3—Annual Cancer Risks for A/D/HE Accidents at LANL

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Individual Noninvolved Worker[c]
Scenario 1	8.86×10^{-6}	3.35×10^{-4}	8.35×10^{-5}
Scenario 2	3.17×10^{-7}	2.4×10^{-4}	2.99×10^{-6}
Scenario 3	2.65×10^{-11}	2.00×10^{-9}	2.50×10^{-10}
Scenario 4	7.86×10^{-10}	3.27×10^{-7}	4.76×10^{-9}
Scenario 5	8.22×10^{-8}	3.42×10^{-5}	4.98×10^{-7}
Scenario 6	6.12×10^{-8}	2.54×10^{-5}	3.69×10^{-7}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 0.5 miles from release.
[b] Based on a projected future population (year 2030) of approximately 712,238 persons residing within 50 miles of TA-16 location.
[c] At a distance of 1,000 meters.

Table C.6-4—Potential Consequences of A/D/HE Accidents at NTS

	Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Scenario 1	0.29	0.000174	112	0.0672	311	0.373
Scenario 2	0.000208	1.25×10^{-7}	0.08	0.000048	0.223	0.000134
Scenario 3	1.74×10^{-8}	1.04×10^{-11}	6.70×10^{-6}	4.02×10^{-9}	1.86×10^{-5}	1.12×10^{-8}
Scenario 4	0.043	2.58E-05	17.7	0.0106	26.3	0.0316
Scenario 5	0.045	0.000027	18.5	0.0111	27.5	0.033
Scenario 6	0.000333	2.00×10^{-7}	0.137	8.22×10^{-5}	0.204	0.000122

Source: Tetra Tech 2008.
[a] At site boundary, 13.7 miles from release.
[b] Based on a projected future population (year 2030) approximately 60,138 persons residing within 50 miles of NTS location.
[c] At 1000 meters from release.

Table C.6-5—Annual Cancer Risks for A/D/HE Accidents at NTS

	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Accident	**Latent Cancer Fatalities**	**Latent Cancer Fatalities**	**Latent Cancer Fatalities**
Scenario 1	1.74×10^{-8}	6.72×10^{-6}	3.73×10^{-5}
Scenario 2	1.25×10^{-9}	4.8×10^{-7}	1.34×10^{-6}
Scenario 3	1.04×10^{-13}	4.02×10^{-11}	1.12×10^{-10}
Scenario 4	2.58×10^{-11}	1.06×10^{-8}	3.16×10^{-8}
Scenario 5	2.7×10^{-9}	1.11×10^{-6}	3.3×10^{-6}
Scenario 6	2.00×10^{-9}	8.22×10^{-7}	1.22×10^{-6}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 13.7 miles from release.
[b] Based on a projected future population (year 2030) approximately 60,138 persons residing within 50 miles of NTS location.
[c] At 1000 meters from release.

Table C.6-6—Potential Consequences of A/D/HE Accidents at Pantex

	Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Scenario 1	3.59	0.00215	1,460	0.876	312	0.374
Scenario 2	0.00257	1.54×10^{-6}	1.04	0.000624	0.224	0.000134
Scenario 3	2.15×10^{-7}	1.29×10^{-10}	8.73×10^{-5}	5.24×10^{-8}	1.87×10^{-5}	1.12×10^{-8}
Scenario 4	0.453	0.000272	208	0.125	25.2	0.0302
Scenario 5	0.474	0.000284	218	0.131	26.3	0.0316
Scenario 6	0.00352	2.11×10^{-6}	1.61	0.000966	0.195	0.000117

Source: Tetra Tech 2008.
[a] At site boundary, approximately 2.2 miles from release.
[b] Based on a projected future population (year 2030) approximately 386,706 persons residing within 50 miles of Pantex location.
[c] At 1000 meters from release.

Table C.6-7—Annual Cancer Risks for A/D/HE Accidents at Pantex

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Scenario 1	2.15×10^{-7}	8.76×10^{-5}	3.74×10^{-5}
Scenario 2	1.54×10^{-8}	6.24×10^{-6}	1.34×10^{-6}
Scenario 3	1.29×10^{-12}	5.24×10^{-10}	1.12×10^{-10}
Scenario 4	2.72×10^{-10}	1.25×10^{-7}	3.02×10^{-8}
Scenario 5	2.84×10^{-8}	1.31×10^{-5}	3.16×10^{-6}
Scenario 6	2.11×10^{-8}	9.66×10^{-6}	1.17×10^{-6}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 2.2 miles from release.
[b] Based on a projected future population (year 2030) approximately 386,706 persons residing within 50 miles of Pantex location.
[c] At 1000 meters from release.

Table C.6-8—Potential Consequences of A/D/HE Accidents at SRS

	Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Scenario 1	0.495	0.000297	2,490	1.49	339	0.407
Scenario 2	0.000354	2.12×10^{-7}	1.79	0.00107	0.243	0.000146
Scenario 3	2.96×10^{-8}	1.78×10^{-11}	0.000149	8.94×10^{-8}	2.03×10^{-5}	1.22×10^{-8}
Scenario 4	0.065	0.000039	368	0.221	12.1	0.00726
Scenario 5	0.068	4.08×10^{-5}	385	0.231	12.6	0.00756
Scenario 6	0.000504	3.02×10^{-7}	2.85	0.00171	0.0936	5.62×10^{-5}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 6.7 miles from release.
[b] Based on a projected future population (year 2030) of 985,980 persons residing within 50 miles of SRS location.
[c] At a distance of 1,000 meters.

Table C.6-9—Annual Cancer Risks for A/D/HE Accidents at SRS

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Scenario 1	2.97×10^{-8}	1.49×10^{-4}	4.07×10^{-5}
Scenario 2	2.12×10^{-9}	1.07×10^{-5}	1.46×10^{-6}
Scenario 3	1.78×10^{-13}	8.94×10^{-10}	1.22×10^{-10}
Scenario 4	3.9×10^{-11}	2.21×10^{-7}	7.26×10^{-9}
Scenario 5	4.08×10^{-9}	2.31×10^{-5}	7.56×10^{-7}
Scenario 6	3.02×10^{-9}	1.71×10^{-5}	5.62×10^{-7}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 6.7 miles from release.
[b] Based on a projected future population (year 2030) of 985,980 persons residing within 50 miles of SRS location.
[c] At a distance of 1,000 meters.

Table C.6-10—Potential Consequences of A/D/HE Accidents at Y-12

	Maximally Exposed Individual[a]		Offsite Population[b]		Noninvolved Worker[c]	
Accident	**Dose (rem)**	**Latent Cancer Fatalities**	**Dose (Person-rem)**	**Latent Cancer Fatalities**	**Dose (rem)**	**Latent Cancer Fatalities**
Scenario 1	54.7	0.0656	48,100	28.9	1,500	1
Scenario 2	0.0392	2.35×10^{-5}	34.4	0.0206	1.08	0.000648
Scenario 3	3.28×10^{-6}	1.97×10^{-9}	0.00288	1.73×10^{-6}	9.02×10^{-5}	5.41×10^{-8}
Scenario 4	2.3	0.00138	5,390	3.23	4.11	0.00247
Scenario 5	2.41	0.00145	5,630	3.38	4.3	0.00258
Scenario 6	0.0179	1.07×10^{-5}	41.8	0.0251	0.0319	1.91×10^{-5}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 1.3 miles from release.
[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.
[c] At 1000 meters from release.

Table C.6-11—Annual Cancer Risks for A/D/HE Accidents at Y-12

Accident	Maximally Exposed Individual[a]	Offsite Population[b]	Noninvolved Worker[c]
Scenario 1	6.56×10^{-6}	2.89×10^{-3}	1×10^{-4}
Scenario 2	2.35×10^{-7}	2.06×10^{-4}	6.48×10^{-6}
Scenario 3	1.97×10^{-11}	1.73×10^{-8}	5.41×10^{-10}
Scenario 4	1.38×10^{-9}	3.23×10^{-6}	2.47×10^{-9}
Scenario 5	1.45×10^{-7}	3.38×10^{-4}	2.58×10^{-7}
Scenario 6	1.07×10^{-7}	2.51×10^{-4}	1.91×10^{-7}

Source: Tetra Tech 2008.
[a] At site boundary, approximately 1.3 miles from release.
[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.
[c] At 1000 meters from release.

C.6.2 Chemical Accident Scenarios

Chlorine has been identified as the hazardous chemical dominating the risk from nonradiological releases for an A/D/HE Center (DOE 1996c). Chlorine is the only chemical with the potential for significant adverse offsite consequences. Since chlorine is not carcinogenic, the consequences of exposure to chlorine (primarily acute effects) differ from the consequences of exposure to radionuclides (potential latent cancers). This difference precludes a direct comparison between the risk and consequences associated with hazardous chemical releases and radionuclide releases. A useful measure of potential human health effects resulting from exposure to non-carcinogenic chemicals is the hazard index. In its most general form, a hazard index is a ratio of the actual exposure of a human receptor to an established exposure limit. If this ratio is appreciably less than unity, no adverse human health effects are expected. If the hazard index is close to unity, some adverse human health effects may occur; and if the hazard index is substantially greater than unity, severe health effects can result.

Numerous exposure limits are available to form a hazard index. Since exposure to an accidental chlorine release is an unlikely, short-duration event, chronic exposure limits are inapplicable. Instead, ERPG values will serve to develop hazard indices for chlorine exposure.

Scenario 7. Chlorine release. The rooms in which chlorine gas would be used would be equipped with a chlorine sensor alarm system that consists of an alarm siren and flashing light located outside the building. The sensor system would be set to activate this alarm at a chlorine concentration of 1.0 part per million in the air. The rooms would also be ventilated with a floor-level exhaust fan and contain an elevated fresh air inlet.

A release of chlorine to the environment due to an earthquake is an unlikely event. Should an earthquake occur with sufficient magnitude to damage a facility that uses chlorine, could release the contents from a maximum of four chlorine cylinders in use. Other chlorine cylinders are not ordinarily expected to contribute to a release initiated by an earthquake. However, in the unlikely event that a chlorine cylinder is stored without its valve cap in place or is substandard structurally when delivered, it is conservatively postulated that Scenario 7 could involve a release from up to six chlorine cylinders. The magnitude of this chlorine release could be as high as 408 kilograms (900 pounds) (Tetra Tech 2008).

Workers in the vicinity of a chlorine release could be exposed to chlorine concentrations in excess of EPRG-3 and threshold levels. No long-term adverse health effects are expected for workers who promptly evacuate the area. For any persons incapable of evacuating the area of the chlorine plume, no serious or irreversible health impacts are expected from EPRG-1 or EPRG-2 exposures since the exposure duration is less than 1 hour. Persons incapable of evacuating an area with EPRG-3 concentrations may experience adverse health impacts depending upon the actual chlorine concentrations encountered and the exposure duration. However, chronic lung disease, electrocardiographic changes, and death have occurred in humans exposed to high concentrations of chlorine as a consequence of industrial accidents (Calabrese 1991).

Tables C.6-12 through C.6-16 depict the potential impacts of conservative modeling of chemical release over the period of 1-hour was based on a spill and subsequent pool with evaporation resulting calculated down-wind concentrations.

Table C.6-12—Chlorine Accident Frequency and Consequences at LANL

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Chlorine	408.23	3	2.8	17.4	32.5	10^{-4}

Source: Tetra Tech 2008.
[a] Site boundary is at a distance of 1.2 miles.

Table C.6-13—Chlorine Accident Frequency and Consequences at NTS

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Chlorine	408.23	3	2.7	17	<0.1	10^{-4}

Source: Tetra Tech 2008.
[a] Site boundary is at a distance of 13.7 miles.

Table C.6-14—Chlorine Accident Frequency and Consequences at Pantex

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Chlorine	408.23	3	2.8	17.5	1.8	10^{-4}

Source: Tetra Tech 2008.
[a] Site boundary is at a distance of 2.2 miles.

Table C.6-15—Chlorine Accident Frequency and Consequences at SRS

Chemical Released	Quantity Released (kg)	ERPG-2 [a]		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Chlorine	408.23	3	1.8	15	<0.2	10^{-4}

Source: Tetra Tech 2008.
[a] Site boundary is at a distance of 6.7 miles.

Table C.6-16—Chlorine Accident Frequency and Consequences at Y-12

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration [a]		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)	
Chlorine	408.23	3	2.3	16	4.5	10^{-4}

Source: Tetra Tech 2008.
[a] Site boundary is at a distance of approximately 1.3 miles.

C.7 TRANSPORTATION RADIOLOGICAL ACCIDENTS

The offsite transportation accident analysis considers the impacts of accidents during the transportation of radiological materials. Under accident conditions, impacts to human health and the environment may result from the release and dispersal of radioactive material. Accidents that could potentially breach the shipping container are represented by a spectrum of accident severities and radioactive release conditions. Historically, most transportation accidents involving radioactive materials have resulted in little or no release of radioactive material from the shipping container. Consequently, the analysis of accident risks takes into account a spectrum of accidents ranging from high-probability accidents of low severity to hypothetical high-severity accidents that have a correspondingly low probability of occurrence. This accident analysis calculates the probabilities and consequences from this spectrum of accidents.

To provide NNSA and the public with a reasonable assessment of radioactive waste transportation accident impacts, two types of analyses were performed. An accident risk assessment was performed that takes into account the probabilities and consequences of a spectrum of potential accident severities using a methodology developed by the NRC (NRC 1977). For the spectrum of accidents considered in the analysis, accident consequences in terms of collective dose to the population within 80 kilometers (50 miles) were multiplied by the accident probabilities to yield collective dose risk using the RADTRAN 5.6/RadCat 2.3 computer code (Weiner 2006).

The impacts for specific alternatives were calculated in units of dose (rem or person-rem). Impacts are further expressed as health risks in terms of estimated latent cancer fatalities in exposed populations. The health risk conversion factor of 0.0006 LCF/person-rem was derived from the Interagency Steering Committee on Radiation Standards report (ISCOR 2002), A Method for Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE).

The risk analyses consider a spectrum of accidents of varying severity. Each first determines the conditional probability that the accident will be of a specified severity. Then, based on the accident environment associated with each severe accident, each models the behavior of the material being shipped and the response of the packaging. The models estimate the fraction of each species of radioactive material that might be released for each of the severe accidents being considered. Results of the RADTRAN runs are provided in Table C.7-1.

Table C.7-1—Results of RADTRAN Accident Runs for a Single Shipment

RADTRAN Run No.	Dose Risk (person-rem)	RADTRAN Run No.	Dose Risk (person-rem)
1	-	9b	4.8×10^{-6}
2a	3.5×10^{-8}	10	2.9×10^{-11}
2b	-	11a	-
3	9.3×10^{-12}	11b	1.5×10^{-4}
4a	6.2×10^{-9}	12a	-
4b	-	12b	2.3×10^{-6}
5	1.8×10^{-11}	13a	4.4×10^{-9}
6	2.2×10^{-11}	13b	6.3×10^{-6}
7	-	14	2.3×10^{-11}
8	-	15a	1.2×10^{-5}
9a	1.6×10^{-8}	15b	3.2×10^{-6}

"-" = no RADTRAN run needed.
Source: DOE 2003b.

References Specific to Appendix C

10 CFR Part 20	Nuclear Regulatory Commission (NRC), "Standards for Protection Against Radiation," *Code of Federal Regulations,* U.S. Government Printing Office, National Archives and Records Administration, Office of the Federal Register, Washington, D.C., Revised January 1, 2008.
29 CFR 1910.95	Occupational Safety and Health Administration (OSHA), "Occupational Safety and Health Standards," Title 29, Labor, Subtitle B, Chapter XVII, Occupational Safety and Health Administration, Department of Labor, *Code of Federal Regulations*, National Archives and Records Administration, Washington D.C., Revised January 1, 2007.
29 CFR 1926.52	Department of Labor (DOL), "Regulations Relating to Labor, Safety and Health Regulations for Construction," *Code of Federal Regulations*, U.S. Government Printing Office, National Archives and Records Administration, Office of the Federal Register, Washington, D.C., Revised July 1, 2007.
40 CFR Part 61	EPA, "Protection of the Environment, National Emission Standards for Hazardous Air Pollutants," *Code of Federal Regulations*, U.S. Government Printing Office, National Archives and Records Administration, Office of the Federal Register, Washington, D.C., Revised July 1, 2007.
40 CFR Part 141	EPA, "Protection of the Environment: National Primary Drinking Water Regulations," *Code of Federal Regulations*, U.S. Government Printing Office, National Archives and Records Administration, Office of the Federal Register, Washington, D.C., Revised July 1, 2007.
51 FR 15618	Council on Environmental Quality (CEQ), "Forty Most Asked Questions Concerning CEQ's NEPA Regulations." *Federal Register*, Vol. 51, U.S. Government Printing Office, National Archives and Records Administration, Office of the Federal Register, Washington, DC, April 25, 1986.
CEDR 2000	CEDR (*Comprehensive Epidemiologic Data Resource)* 2000, Internet file, http://cedr.lbl.gov, accessed February 2000.
DOE Order 430.1B	DOE, *Facility Safety*, U.S. Department of Energy, Office of Environment, Safety and Health, Washington, D.C., December 22, 2005.

DOE 1999f DOE, *Draft Agenda for Public Health Activities for Fiscal Years 1999 and 2000 U.S. Department of Energy Sites*, U.S. Department of Energy and U.S. Department of Health and Human Services, Washington, D.C., April 1999.

DOE 1996c DOE, *Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components*, DOE/EIS-0225, U.S. Department of Energy Albuquerque Operations Office, Albuquerque, New Mexico, November.

DOE 1996d DOE, *Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, DOE/EIS-0236, U.S. Department of Energy, Washington, D.C., 1996.

DOE 2002d DOE, *Radiation Risk Estimation from Total Effective Dose Equivalents (TEDEs)*, Office of Environmental Policy and Guidance, Washington, D.C., August 9.

DOE 2003b DOE, *Draft Supplemental Programmatic Environmental Impact Statement on Stockpile Stewardship and Management for a Modern Pit Facility*, DOE/EIS-236-S2, May 2003.

DOE 2005a DOE, *Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement*, DOE/EIS-0348 and DOE/EIS-0236-S3, U.S. Department of Energy, National Nuclear Security Administration, Washington, D.C., March 2005.

EPA 1989 EPA, *Risk Assessments Methodology, Environmental Impact Statement, NESHAPs for Radionuclides, Background Information*. Vol. 1. EPA/520/1-89-005. U.S. Environmental Protection Agency, Washington, D.C.

EPA 2008 EPA, *Radiation Risk Assessment Software: CAP88 and CAP88 PC*, Available at: http://www.epa.gov/radiation/assessment/CAP88/index.html, Accessed: June-July 2008.

Jacobs 1993 Jacobs Engineering Group, *Natural Phenomena Hazards Assessment for the Pantex Plant*, Jacobs Engineering Group, Amarillo, Texas, October 1993. **Unclassified Controlled Nuclear Information**

Jacobs 1993a	Jacobs Engineering Group, *Chemical High Explosives Hazards Assessment for the Pantex Plant*, Jacobs Engineering Group, Amarillo, Texas, October 1993.
LANL 1999	LANL, *Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico*, DOE/EIS-0238, U.S. Department of Energy, Washington, D.C., 1999.
LANL 1999b	LANL, *Final Supplement Analysis for Pit Manufacturing Facilities at Los Alamos National Laboratory, Stockpile Stewardship and Management Programmatic Environmental Impact Statement*, DOE/EIS-0236/SA-6, U.S. Department of Energy, Washington, D.C., 1999.
Lawrence 2002	Lawrence, Andy, Memorandum on the *Radiation Risk Estimation From Total Effective Dose Equivalents (TEDEs)*, Office of Environmental Policy and Guidance, Washington, D.C., August 9, 2002.
Maltese et al., 1996	Maltese, J.G., W.E. Joyce, *A.L.* Toblin, and S.R. Tammara, *Topical Report - Supporting Documentation for the Accident Impacts Presented in the Stockpile Stewardship and Management Programmatic Environmental Impact Statement*, 1996.
NCRP 1993	National Council on Radiation Protection and Measurement (NCRP), *Risk Estimates for Radiation Protection*, NCRP Report No. 115, 1993, First Edition, First Printing. (ISBN: 0929600347), National Council on Radiation Protection, Bethesda, MD, December 31, 1993.
NRC 1977	Nuclear Regulatory Commission (NRC), *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50*, Regulatory Guide 1.109, Appendix I, Revision 1, Nuclear Regulatory Commission Office of Standards Development, Washington, D.C., October 1977.
NUREG 1990	Nuclear Regulatory Commission Regulation, *MELCOR Accident Consequence Code System (MACCS)*, NUREG/CR-4691-Vol. 3; SAND-86-1562-Vol. 3, Nuclear Regulatory Commission, Washington, D.C., February 1990.

Pantex 1995j — Pantex, *Basis for Interim Operations for the Pantex Plant*, Amarillo, Texas, Pantex Plant, June 1995, Unclassified Controlled Nuclear Information.

Ries et al. 2002 — National Council on Radiation Protection and Measurement (NCRP), *Risk Estimates for Radiation Protection*, NCRP Report No. 115, 1993, First Edition, First Printing. (ISBN: 0929600347), National Council on Radiation Protection, Bethesda, MD, December 31, 1993.

Tetra Tech 2008 — Tetra Tech, Inc., *Topical Report, Supporting Documentation for the Accident Impacts and Normal Operations Presented in the Complex 2030 Supplemental Programmatic Environmental Impact Statement*, 2008.

Weiner et al. 2006 — R.F. Weiner, Osborn, D.M., Mills, G.S., Hinojosa, D., Heames, T.J., and Orcutt, D.J., *RadCat 2.3 User Guide*, SAND2006-6315, Sandia National laboratories, Albuquerque, NM, October 2006.